The Royal Navy on the threshold of modern anti-submarine warfare, 1944-1949

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Abstract

Until 1944 U-boats operated as submersible torpedo craft, rather than as true submarines. However, growing Allied anti-submarine measures forced the Germans to adopt submerged operations, made practicable by the addition of the schnorkel, while in parallel they began developing U-boats capable of high speed and long endurance underwater. The Royal Navy countered with tactical adaptation and an intensive training programme both against the schnorkel-fitted U-boats and the potential threat of the fast types, which, though they did not become operational, became the benchmark of the post-war Russian submarine challenge.

Post-war Royal Navy doctrine was developed by three professional anti-submarine officers: Burnett, Ormsby and Mosse. They had to deal with a difficult problem, for, by remaining continuously submerged and firing at longer ranges, the fast submarines were harder to detect and even harder to attack. In 1948-49, the first tactical sea exercises against fast submarines confirmed the limitations of existing anti-submarine equipment. New anti-submarine technology was a long way off, so immediate remedies were tactical. Convoying remained the cornerstone of anti-submarine defence, but was combined with offensive measures, which extended from the convoy's boundary to the enemy's homeland. Individual actions emphasized rapid, aggressive, co-ordinated and persistent responses, however, ships were once more restricted to barrage attacks and aircraft lacked any effective submarine-killing weapon. Individual submarines could be very dangerous if they attacked a convoy, although they were still plagued with the thorny problem of finding the convoys without supporting air reconnaissance.

This thesis shows that the Royal Navy's response to modern anti-submarine warfare was rooted in the tactical concepts developed in the interwar period and the Second World War. It saw anti-submarine doctrine as consisting of "defensive" and "offensive" tactics, not as alternatives, as they have usually been depicted, but as parts of a symbiotic and hypostatic whole.

Acknowledgements

The author owes a debt to the staff of the many archives listed in the Bibliography. Especially helpful was Julie Ash at the National Archives at Kew (formerly the Public Record Office), and Kate Tildesley and Jenny Wraight of the Naval Historical Branch and Admiralty Library. Every archive provided cheerful and unfailing help in unearthing and producing the primary sources upon which this thesis is based. My thanks also go to others for access to privately held papers, including: Rear Admiral J.H. Adams, CB, LVO, David Lees, K.T. Nethercoate-Bryant (of the Submarine Old Comrades Association, Gatwick), Lieutenant Commander Paul Mallett, SAN(CF), Ret'd, Electrical Sub Lieutenant M. Walford, RNVR, and Dr. Gary Weir, Naval Historical Center, Washington. My thanks also go to Michael Whitby, William Glover, Lieutenant Colonel John Abbatiello, USAF, Lieutenant Commander George Franklin, RN, Commander David Stevens, RAN, Ron Curtis, T.H. Pratt, David Webb and Dr. Susan Cunningham who all generously shared their research and insights. For instilling an obsessive interest in history my first teacher, Mr. Weeks, takes full credit, but it was Professor Geoffrey Till, David Waters and the late Commander Richard Compton-Hall in their own ways, each provided the inspiration and impetus for this particular avenue of research. For his subtle guidance I owe a debt to my supervisor, Professor Andrew Lambert, as I do to Lieutenant Commander Doug McLean, CF, Dr. Joe Maiolo, Dr. Robin Woolven and Peter Nash who read initial drafts, corrected innumerable errors of spelling and syntax, and asked many searching questions. Lastly, sustaining the effort was made easy by many friends who rallied to help and nag. I am especially appreciative of the company and encouragements during many dinners with George Karger and John Salmon, as well as the "Ol' Fogies", Bronwyn Fysh, Tony Hampshire, John Ross, Nick Black, Dr. Warwick Brown and others already mentioned. My thanks to them all and to the staff of the Whitehall Café for the best espresso in Britain and the Coffee House in Stow-on-the-Wold for many a great panini.

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Abbreviations

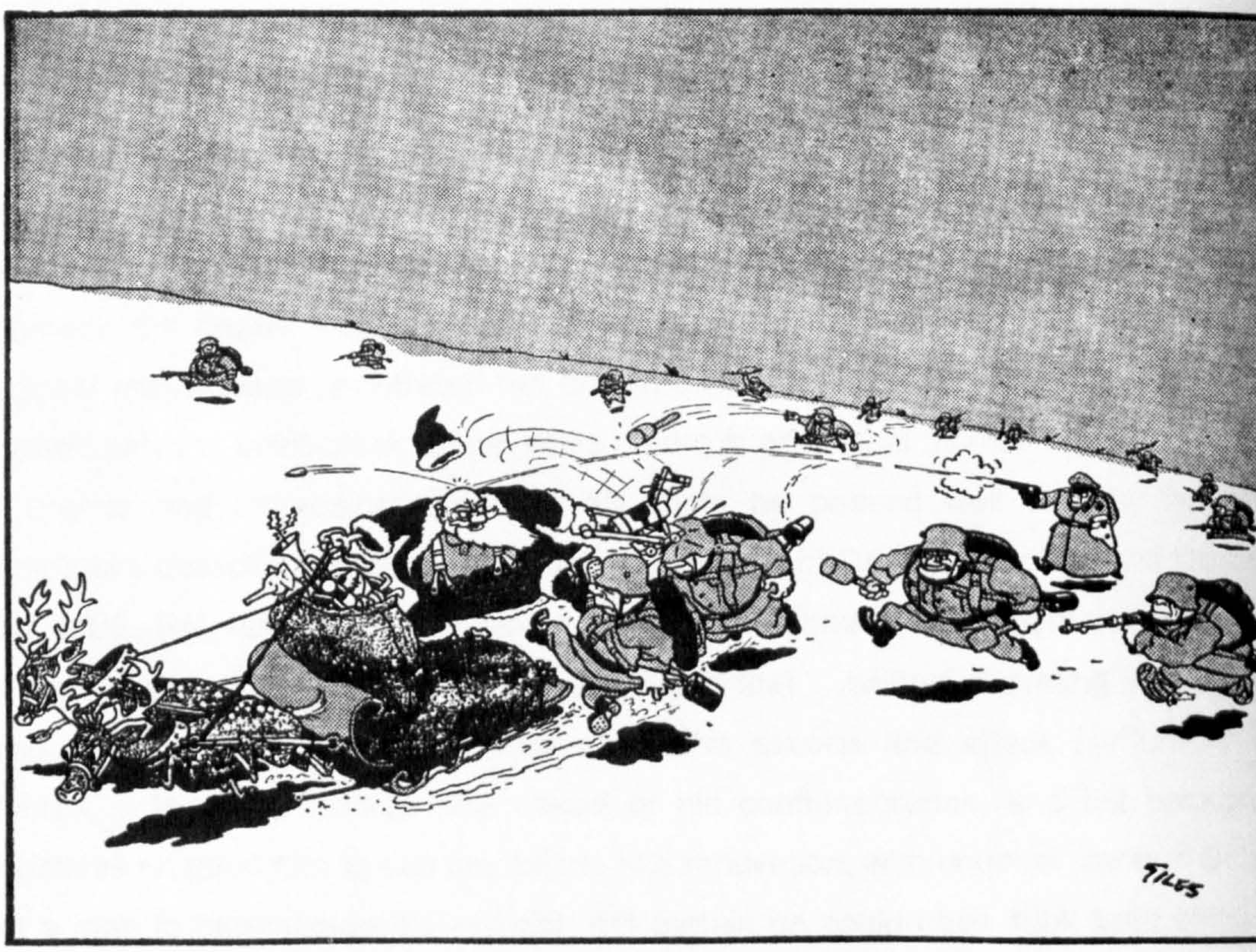
A/A	Anti-Aircraft
ACAS	Assistant Chief of Air Staff
ACHQ	Area Combined Headquarters
ACI(s)	Admiralty Convoy Instructions
ACNS	Assistant Chief of Naval Staff
ACNS(UT)	Assistant Chief of Naval Staff (U-boats & Trade)
A/D	Aircraft Direction
AEW	Airborne Early Warning
AIO	Action Information Organization (sometimes AIC – or Action Information Centre – or, Operations Room, equivalent to the US CIC, or Combat information Centre)
ARL	Admiralty Research Laboratory
A/S	Anti-Submarine
Asdic	Supersonic echo ranging equipment (equivalent to US Sonar)
A/SEE	Anti-Submarine Experimental Establishment. Also see HMA/SEE – Later became HMUDE
ASW	Anti-Submarine Warfare
ASWORG	Anti-Submarine Warfare Operations Research Group (Tenth Fleet, USN) (A rough equivalent to DNOR)
ATW	Ahead Throwing Weapon (such as, Hedgehog and Squid)
BAD	British Admiralty Delegation, Washington, DC.
BdU	*Befehlshaber der Unterseeboote*, the U-boat High Command
C-in-C	Commander-in-Chief
C-in-C, WA	Commander-in-Chief, Western Approaches
CAFO	Confidential Admiralty Fleet Orders
CAOR	Chief Advisor on Operational Research
CCDU	Coastal Command Development Unit
CVE	Escort Carrier
DAUD	Director of Anti-U-Boat Division, Admiralty
CNO	Chief of Naval Operations (US Navy)
D of Ops	Director of Operations, Air Ministry
DASW	Director of Anti-Submarine Warfare Division, Admiralty
DAUD	Director of Anti-U-Boat Division
DAW	Director of Air Warfare
DDOps(M)	Deputy Director of Operations (Maritime), Air Ministry
6DF	Sixth Destroyer Flotilla
D/F	Direction Finder (or Finding)

DNC	Director of Naval Construction, Admiralty
DNOR	Director of Naval Operational Research [see also CAOR]
DOD	Director of Operations Division, Admiralty
D of P	Director of Plans Division, Admiralty
DTASW	Director of Torpedo, Anti-Submarine and Mine Warfare Division, Admiralty
DTM	Director of Torpedoes and Mining, Admiralty
DTSD	Director of Tactical and Staff Duties Division, Admiralty
4EF	Fourth Escort Flotilla
EGx	x^{th} Escort Group
FoC	Furthest-on-Circle
Gnat	German Naval Acoustic Torpedo, otherwise known as in Britain as "Curly", and by the German Navy as *Zaunkönig.*
HE	Hydrophone Effect
H/F	High Frequency Radio, sometimes shown as "HF"
HF/DF	High Frequency [Radio] Direction Finding (Colloquially known as "Huff-Duff")
HM	His or Her Majesty's...(Ship, Submarine, etc.)
HMA/SEE	Her Majesty's Anti-Submarine Experimental Establishment, Fairlie. See also A/SEE
HMS	HM Ship
HMCS	HM Canadian Ship
HMUDE	Her Majesty's Underwater Detection Establishment, Portland
HQ	Headquarters
HTP	High Test Peroxide (otherwise known as Hydrogen Peroxide - H_2O_2 – or Ingolin, the power source for the Walter turbine)
LLSuA	Limited Lines of Submerged Approach
MAD	Magnetic Anomaly Detector
MLA	Mean Line of Advance
NavTecMisEu	US Naval Technical Mission in Europe
NATO	North Atlantic Treaty Organisation
NELM	North East Atlantic and Mediterranean, USN Command
NID	Naval Intelligence Division
NOIC	Naval Officer-in-Charge
POBRY	Standard 5-sonobuoy pattern (Derived from colours assigned to individual buoys: purple, orange, blue, red and yellow. Green was also available)
PoW	Prisoner(s)-of-War
PPI	Plan Position Indicator (Radar or Asdic display)

QH	Radio Navigation Aid (similar to the RAF radio navigation aid, GEE, and forerunner of modern Decca radio navigation system)
RAF	Royal Air Force
RAN	Royal Australian Navy
RAAF	Royal Australian Air Force
RCAF	Royal Canadian Air Force
RCN	Royal Canadian Navy
RN	Royal Navy
RP	Rocket Projectile
SASO	Senior Air Staff Officer, of an RAF Command
SAWC	Joint (Admiralty and Air Ministry) Sea/Air Warfare Committee
σ (Sigma)	Symbol denoting the statistical measure "standard deviation".
SO	Senior Officer (of Escort Group)
TDZ	Torpedo Danger Zone
UHF	Ultra High Frequency (radio)
US	United States
USN	United States Navy
USNR	United States Naval Reserve
UWD	Underwater Weapons Department, Admiralty and USN
VCNS	Vice Chief of the Naval Staff
VHF	Very High Frequency (radio)
VLF	Very Low Frequency (acoustics)

<u>Plate 1: "Ruddy Convoy" Cartoon</u>

(Sunday Express, 26 December 1943)



"This is the last time I do this ruddy trip without a convoy."

Sunday Express, Dec. 26th, 1943

Introduction

Preamble

As the Second World War came to a close, Korvetten-Kapitan Adalbert Schnee took the new Type XXI U-boat *U-2511* on its first operational patrol {*Plate 2*}. These streamlined boats were capable of high underwater speed and (by use of the schnorkel breathing tube) of continuous submerged operations. Operating *U-2511*, to the North of the Shetlands, Schnee, so the literature relates, found himself in an excellent position to attack the cruiser HMS *Norfolk*, screened by a single destroyer. Some accounts suggest that Schnee penetrated the cruiser's destroyer screen and simulated firing a torpedo salvo at point-blank range, while others suggest that by making a 30° alteration of course and increasing speed to 16 knots he passed well outside the British destroyer's detection range and thus avoided contact.[1] Commander Richard Compton-Hall, MBE, RN, himself an experienced submarine commander, spent some time with Schnee to assess his capabilities and concluded that '...without intending (I am sure) to brag, ...[he] felt able to run circles round the escorts and attack favourably if he wanted. ...He was, I think, way ahead of his contemporaries, and his background doubtless enabled him to see the future, and innovation, with unusual clarity.'[2] Schnee, not a man to camouflage his exploits, felt certain he could have sunk both ships with the greatest of ease. However, he had just received the signal from Dönitz ordering the cessation of hostilities, so he made for his base at Bergen, leaving the British unaware of their narrow escape.[3]

The incident, itself, seems to have made little impact on the Admiralty at the time. Indeed, by the end of the war the British already had a firm grasp of the nature of this threat and had evolved anti-submarine measures to deal with it. Yet it the subsequent literature, Schnee's "attack" is depicted with greater authority than it deserves, for the

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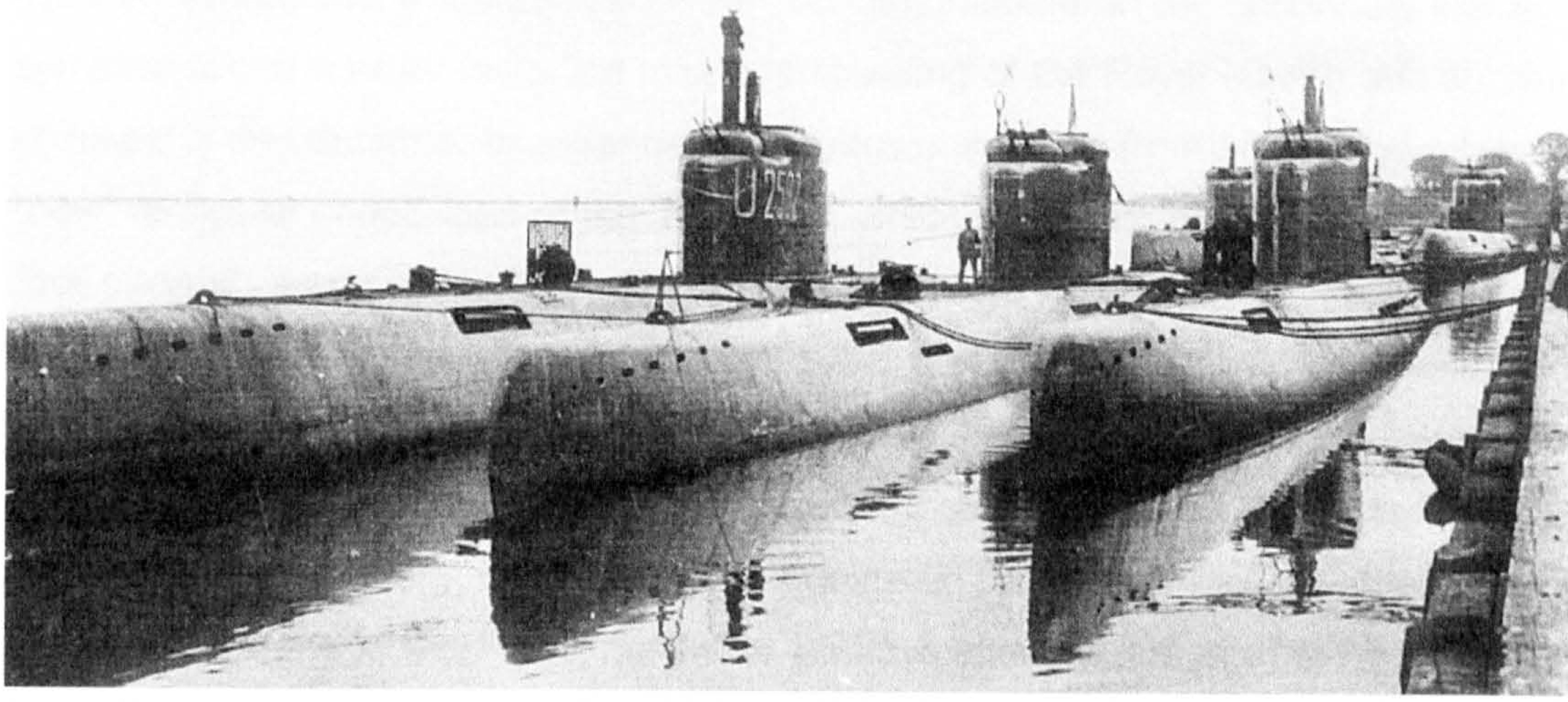
[1] Karl Doenitz, *Memoirs: Ten Years and Twenty Days*, tr. R.H. Stevens, intro. Jürgen Rohwer (London: Greenhill Books, 1990), p. 429; Kenneth Wynn, *U-Boat Operations of the Second World War*, Vol. 2: *Career Histories, U511-UIT25* (London: Chatham Publishing, 1998), pp. 256-257; Jordan Vause, *Wolf: U-boat Commanders in World War II* (Shrewsbury: Airlife, 1997), pp. 202-203; F.H. Hinsley, E.E. Thomas, C.A.G. Simkins and C.F.G. Ransom, *British Intelligence in the Second World War: Its Influence on Strategy and Operations*, Vol. III, Part 2 (London: HMSO, 1988), p. 631.

[2] Richard Compton-Hall, e-mails 20/06/00 11:27:31 and 16:07:15.

[3] 'Bergen,' in, 'Report on Interrogation of German Naval Staff Officers of the U-Boat Arm at Flensburg and Bergen,' Group Captain Gates, CC/s.17384 A/U Ops., 6 June 1945, Gretton Papers, MSS/93/008, NMM(G).

Plate 2: Three Type XXIs, including *U-2511* (centre)

(Bibliotthek fur Zeitgeschichte: Sleek Type XXI U-boats, 115/11)



surviving evidence to support the event is nebulous.[4] Nevertheless, it has entered the folklore of the Battle of the Atlantic as epitomising the power of these new U-boats and the deadly threat they posed to British shipping. This view is fuelled both by the technological novelty supposed to be incorporated into these new German U-boats, and because specimens of these boats were acquired by the Russians at the end of the war. Worse still, the portrayal of the "Schnee incident" in the secondary literature is symptomatic of a wider historical misunderstanding of the Royal Navy's anti-submarine philosophy and doctrine. In essence, the confusions stems from an exaggeration of the "new" technical capabilities of the Type XXI, which would have been pitted against the "out-of-date", wartime technology of the Royal Navy. Realising this, according to this view, the British gradually abandoned their war-winning, but "defensive", convoy strategy which was now likely to be ineffective. This was reinforced by the Royal Navy's ambivalence about convoy and its institutional bias towards aggressive methods. As a corollary, the Royal Navy gravitated towards "offensive" operations, just as they had done in the First World War and the opening phase of the Second World War. The argument, however, is not supported by the primary evidence.

The Objectives of the Thesis

This thesis provides a new interpretation of the Royal Navy's anti-submarine philosophy – one that unequivocally shows that the "defensive" and "offensive" operations were consistently visualized (in both peace and war) as interdependent, symbiotic parts of a holistic anti-submarine strategy and not as alternative strategies. This new analysis provides a new basis against which to reassess the British approach to anti-submarine warfare in the first half of the twentieth century and, in the process, depicts the Royal Navy and, especially, the Admiralty as more subtle and forward-thinking organisations than is generally supposed. Moreover, this thesis takes the radical approach of treating the "middle management" (that is, the Commanders and Captains), of the Admiralty and Royal Navy commands as the main authors of development, rather than as puppets reacting to the bidding of senior officers.

Background and Literature

The heresy of dividing the tactical application of anti-submarine (A/S) warfare into "defensive" or "offensive" operations has become widespread and is followed, albeit

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[4] Marc Milner, *The U-boat Hunters: The Royal Canadian Navy and the Offensive against Germany's Submarines* (Annapolis, Maryland: Naval Institute Press, 1994), p. 254.

inconsistently, in the current *British Maritime Doctrine* Manual.[5] The modern view was cemented in place by the post-war work of the Admiralty and Official Historians, and has underpinned the analysis of many subsequent historians. In the mid-1950s, the Admiralty's Historical Section thought they were witnessing a growing acceptance of the "Convoy is Defensive" school of thought within the Service. A section of naval opinion, the Historians held, viewed the convoy system as '...the embodiment of the defensive,' but this, they added, '...is not substantiated by the facts of war ascertained by rigorous historical research.' Indeed, their analysis revealed that, in both World Wars, '...of all the measures we adopted, the convoy system alone provided the means for waging unremitting and highly remunerative offensive action....'[6] They drove home their point with a statistical comparison, albeit only up to May 1943, of the effectiveness of "convoy" forces in destroying U-boats, as opposed to other operations, such as hunting patrols, transit offensives, mining and bombing of bases, that were invariably seen as "offensive". The writers claimed that 23% of the U-boats were sunk by "offensive" operations but 65% were destroyed by convoy escorts and their supports, with the remainder being lost to various other means.[7] Their subsequent Staff History was somewhat more muted but emphasised these same ideas.[8] They were also echoed by the Official Historian, who noted that there was a '...widely held but fallacious belief that [these] so-called "offensive" measures against the U-boats could provide an effective alternative to convoy.'[9] The point has been amplified by historians, who also point to the concomitant inability of the Admiralty to "learn from history".[10] However, as this thesis unequivocally demonstrates, this is a jaundiced and partial view of the Royal Navy's A/S doctrine.

The weakness of the previous accounts of the Battle of the Atlantic is that they concentrate on an apparently endless succession of great convoy battles in 1942-43. Although there are several valuable and critical analyses, the depiction of these battles

[5] Naval Staff Directorate, *British Maritime Doctrine*, 2 Edn., BR1806, (London: HMSO, 1999). A correction had been submitted by the author to this manual.
[6] 'A "New Look" at "Offence" and "Defence": The Anti-U-Boat Campaign, 1939-1945, A Brief Statement of Facts,' F. Barley and D.W. Waters, Historical Section, 15 October 1955, DWW24, Box PT134, NHB [emphasis supplied]. This paper is reproduced at Appendix 1.
[7] 'A "New Look" at "Offence" and "Defence",' NHB.
[8] Eric J. Grove (ed.), *The Defeat of the Enemy Attack on Shipping, 1939-1945*, revised edn. (Aldershot: Ashgate for The Navy Records Society, 1997), pp. 47-49.
[9] Stephen Roskill, *The War at Sea 1939-1945*, Vol. I: *The Defensive* (London: HMSO, 1954), p. 134.
[10] P. Gretton, 'Why Don't We Learn From History,' *The Naval Review* (January 1958). Gretton drew much of his inspiration from the Historical Section. Recent scholarship has begun to unpick these ideas, see: Joseph A. Maiolo, *The Royal Navy and Nazi Germany, 1933-39: A Study in Appeasement and the Origins of the Second World War* (London: Macmillan Press, 1998) and George Franklin, *Britain's Anti-Submarine Capability, 1919-1939* (London: Frank Cass, 2003). The latter, however, still contains a number of myth-ridden conclusions.

against packs of U-boats operating on the surface at night leads to an exaggeration of their overall historical importance, for, in many respects, these battles are perturbations in the overall progress of submarine (and hence anti-submarine) warfare.[11] Furthermore, as Professor Zimmerman points out:

> Research on the Battle [of the Atlantic] has tended to focus on either the operational *or* the technological developments. Operational historians have been content simply to add new technology to their discussions of convoy actions. These historians have provided little or no discussion on why and how the new weapons systems were developed, and have ignored any mention of the new tactical doctrine and training programmes introduced to make use of them.[12]

This thesis redresses such narrow accounts by examining a number of wider themes barely touched in the existing literature.[13] This thesis shows that the inshore campaign in 1944-45 against U-boats fitted with the schnorkel and the potential threat of the Type XXI each had a much greater impact on post-war A/S doctrine than the earlier battles against the wolf-packs. This influence is inadequately covered in most accounts of post-war Royal Navy doctrine and, where it is referred to, the conclusion is of a bleak outlook for A/S warfare. The most balanced view, albeit from an American perspective, is provided by Professor Palmer's *Origins of the Maritime Strategy*, although his account somewhat over-eggs the potential of the new fast submarines.[14] The development of post-war doctrine in the Royal Navy has received little critical analysis. Dr. Grove's *From Vanguard to Trident* surveys the evolution of post-war British naval policy but the depth of tactical and technical analysis is relatively shallow.[15] The

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[11] Jürgen Rohwer, *The Critical Convoy Battles of March 1943: The Battle for HX.229/SC.122* (London: Ian Allan, 1977); David Syrett, *The Defeat of the German U-Boats: The Battle of the Atlantic* (Columbia: South Carolina University Press, 1994) and Michael Gannon, *Black May: The Epic Story of the Allies' Defeat of the German U-Boats in May 1943* (London: Aurum Press, 1998); W.A.B. Douglas, *The Creation of a National Air Force: The Official History of the Royal Canadian Air Force*, Vol. II (Toronto: University of Toronto Press, 1986).

[12] David Zimmerman, 'Tactics and Technology', in Stephen Howarth and Derek Law (eds.), *The Battle of the Atlantic 1939-1945: The 50th Anniversary International Naval Conference* (London: Greenhill Books, 1994), p. 476 [emphasis supplied].

[13] The exceptions are: Marc Milner, 'The Dawn of Modern Anti-Submarine Warfare: Allied responses to the U-boats, 1944-45,' RUSI Journal (Spring 1989), pp. 61-68; Douglas M. McLean, 'Confronting Technological and Tactical Change: Allied Antisubmarine Warfare in the Last Year of the Battle of the Atlantic', *Naval War College Review*, Vol. 47, No. 1 (1994), pp. 87-104, and, 'The Last Cruel Winter: The RCN Support Groups and the U-Boat Schnorkel Offensive' (MA, Royal Military College of Canada, March 1992); also M. Llewellyn-Jones, 'Trials with HM Submarine *Seraph* and British Preparations to Defeat the Type XXI U-Boat, September–October, 1944,' *The Mariner's Mirror*, Vol. 86, No. 4 (November 2000), pp. 434-451, and, 'The Pursuit of Realism: British Anti-Submarine Tactics and Training to Counter the Fast Submarine,' in, John Reeve and David Stevens (eds.), *The Face of Naval Battle: The Human Experience of Modern War at Sea* (Crows Nest, NSW, Australia: Allen & Unwin, 2003), pp. 219-239.

[14] Michael A. Palmer, *Origins of the Maritime Strategy: The Development of American Naval Strategy, 1945-55* (Annapolis: Naval Institute Press, 1990).

[15] Eric J. Grove, *Vanguard to Trident: British Naval Policy since World War II* (London: The Bodley Head, 1987).

corresponding developments in A/S warfare for the Royal Air Force are almost entirely absent. The series of books by Dr. Friedman are useful for technological issues, the principle one being his review of *The Postwar Naval Revolution*.[16] This book covers anti-submarine technical developments for both air and naval forces, but it cobbles together a miscellany of information with little analysis or emphasis. Dr. Hackmann has provided a detailed, if occasionally convoluted, study of the development of acoustic means of detecting submarines, but is weak on the interrelationship to A/S tactics.[17]

This thesis takes a different standpoint by deliberately analysing the late war operations and their influences on post-war doctrine development. This analysis exposes the difficult nature of A/S warfare. Submarines are usually hard to locate – a factor which submariners try to exploit by optimising their operations to create swift attacks from an ambush, after which they endeavour to withdraw from any tactical situation in order to re-initiate an attack at a time and place where again they hope to enjoy the advantage of initial stealth. Anti-submarine forces, conversely, strive for deliberate tactical engagements with submarines so that their superior advantages of tactical co-ordination and numbers can be brought to bear. Submarines can somewhat emulate the escort advantage of mass by bringing more submarines into the area of a specific convoy battle but they can never achieve the same benefit from a concentrated mass because of the inherent tension between coordination (and hence the need for overt communication) and stealth. These tactical preferences of the opponents in A/S warfare therefore provide a basic continuity to these operations.[18] These aspects are crucial to understanding how decisions on A/S warfare doctrine came to be made.

The small group of officers who undertook this work in the Admiralty after the Second World War, certainly understood these issues. These men, Captain P.W. Burnett, DSO, DSC, RN, Commander G.A.G. Ormsby, DSO, DSC, RN, and Lieutenant Commander J.P. Mosse, DSC, RN, were all career officers with distinguished wartime records, and all were anti-submarine specialists *{Plate 3}*. The A/S doctrine they championed in 1946-48 drew in large measure on their wartime experiences. That, in turn, had been conditioned by their pre-war anti-submarine specialist education on

[16] Norman Friedman, *The Postwar Naval Revolution* (London: Conway, 1986); Norman Friedman, *Submarine Design and Development* (London: Conway, 1984); Norman Friedman, *U.S. Submarines Since 1945: An Illustrated Design History* (Annapolis: U.S. Naval Institute Press, 1994).
[17] Willem Hackmann, *Seek & Strike: Sonar, Anti-submarine Warfare and the Royal Navy 1914-54* (London: HMSO, 1984).
[18] 'Philosophical Ramblings,' Doug McLean, e-mail, 01/11/03 21:13:28 GMT

Plate 3: Commanders P.W. Burnett and G.A.G. Ormsby

(IWM)

Commander P.W. Burnett (centre)

Commander G.A.G. Ormsby (centre),

professional courses and in subsequent appointments during the 1930s.[19] The doctrine they were taught was rooted in the operations in the last years of the First World War, and modified by the subsequent development of "asdic" (later known as sonar) acoustic echo-location of submarines. The progress in the tenets of A/S warfare from 1917 onwards therefore form the template for this thesis until 1949, when Burnett and immediate his successors had laid the foundations of the doctrine which served the Royal Navy well for several decades. There was, of course, subsequent modification, in part because of the formation of NATO – with its greater emphasis on alliance warfare – but also to take account of the improved weapons and sensors that began to appear in volume with the rearmament spurred by the Cold War and the potential of the Russian submarine threat.

The change in submarine warfare occurred in 1944 when the Germans began to operate U-boats on war patrols during which they remained submerged throughout, made possible by the introduction of the schnorkel. In parallel the enemy was developing new U-boat types capable of high submerged speed. Thus 1944 marks the dawning of modern A/S warfare, though contemporary opinions were divided on whether this represented a revolution or simply the evolution of methods used to deal with older submarines. Technological remedies, by and large, did not to appear until the 1950s and the equipment itself was in part an amalgam of gear initially developed to meet a different requirement together with wholly new concepts which, however, did not become operationally effective for another decade. This thesis shows that, contrary to most expectations, the Royal Navy approached the problem of the fast submarine in the post-war era by means of tactical adaptation to optimise existing A/S equipment. Their doctrine, presented here, has been derived from an extensive analysis of the contemporary tactical manuals and doctrine papers which were written by naval officers with considerable A/S experience during or in the immediate aftermath of the war. They also benefited from the close interaction between the naval and scientific communities in the Admiralty and Commands. As a result the documents tend to be more pragmatic than theoretical, and therefore do not present the historian with the overly geometric and formulaic vista found in age-of-sail treatise.[20]

Even so, these manuals and papers present analytical challenges. The surviving papers are voluminous and have to be condensed so that their often arcane nature becomes more easily digestible, but without over-simplification. There is no guarantee

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[19] John Mosse, 'Half a Lifetime,' Part II, August 1986, IWM 90/23/1, pp. 1-2.
[20] N.A.M. Rodger, 'Image and Reality in Eighteenth-Century Naval Tactics,' *The Mariner's Mirror*, Vol. 89, No. 3 (August 2003), pp. 280-296.

that men at sea actually followed them to the letter – indeed the opposite is clearly the case.[21] Furthermore, in the confusion, uncertainty and dynamics of battle, the skill and aggression or passivity of leaders, the vagaries of the environment, and so on, mean that individual actions are unique. To see the effect, and to test how tactics were actually put into effect, a number of wartime operations were examined. There is not space here to recount the detail, so the analysis has been used to provide a more discerning interpretation of the formal tactical manuals. Peacetime exercises provide another challenge because of their "artificiality". As the Admiralty frequently noted, exercises gave false impressions of the tactical outcome because of the inhibiting effects of safety rules and because the "enemy" was unlikely to respond as he would in war – he might even cheat![22] Thus when Burnett, and the others, came to set out the post-war doctrine they often did so against a background of little hard evidence. The threat they had to deal with, if not wholly new, presented itself in ambiguous ways.

Assumptions and Limitations of Scope

Certain assumptions have been made. Firstly, that the tactical and technological interaction can be discussed for the period of 1944 to 1949 with little reference to finance (at least for A/S operations) for two reasons. To begin with, the cost of tactical development revolves around the provision of sea and shore-based trials. Whilst these were not lavish, there is little evidence to support the contention that tactical development was seriously curtailed by lack of resources caused by financial restriction. The thesis demonstrates that quite the opposite was the case. Tactical development (even post-war) proceeded at a reasonable pace, because much of it was a cerebral process. As for the provision of new technology, the sheer complexity of some of the developments (especially asdic and acoustic torpedoes) was as much a limiting factor as any lack of material or personnel (which was in some important areas soon rectified).[23] These equipments were deployed, as expected in the early 1950s. Of course, post-war financial restrictions did curtail the strategic application of some tactical options, notably by limiting the more offensive force levels and deployment patterns. But it is easy to forget that there were resource limitations in wartime too. To some extent post-war shortcomings were redressed by the rearmament programme of the early 1950s which coincided with the availability of new A/S equipment. However,

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[21] 'HMS *Conn*, Report of Proceedings, 11 January to 2 February 1945,' Lieutenant Commander Raymond Hart, DSC, RN, Senior Officer 21st Escort Group, 5 February 1945, ADM 217/755.
[22] Commander Richard Compton-Hall, Interview, 26 February 2000.
[23] 'HMUDE Summary of Progress,' 1 December 1949, NAA(M): MP1049/5, 1968/2/800.

the way the ships and equipment were to be used remained as planned despite financial constraints.

The impact of atomic weapons seems to have had little effect on the way the British conceived of their post-war A/S doctrine until the next decade. They maintained a keen interest in the likely effects on sea warfare, and whatever the outcome of arguments over "broken-backed warfare", if war at sea was protracted, then the defence of trade remained a central concern of the Royal Navy.[24] British concepts of A/S warfare were probably more affected by the demands of the Cold War, than by the direct influence of the atomic bomb. There are also other aspects of anti-submarine warfare that will not be covered in detail. Mine warfare was employed extensively during the war and formed a substantial element of post-war A/S planning, both as an offensive weapon in the enemy's own waters, and defensively to protect shipping routes and harbours. Mining is a topic which deserves a full treatment in its own right but space here precludes more than brief mention of it. Similarly, submarines were employed in both world wars on A/S operations, however their use this role bears only obliquely on most of the narrative presented here, until between 1947-48 when A/S warfare became their primary mission. Lastly, the case for A/S aircraft is more awkward. Because aircraft, as will be seen, lost their power to destroy submarines by the introduction of the schnorkel, they played a less central role in anti-submarine warfare from 1944 onwards and did not begin to recover their primacy until new acoustic detection and weapon technology became available towards the end of the 1950s. For this reason, there is less emphasis in this thesis on airborne tactics than on those used by surface forces.

Structure of the Thesis

The main thematic strands of this thesis are heavily intertwined and treating them separately risks losing the essential complexity of A/S warfare. For this reason, the thesis is presented as a chronological narrative that is, unavoidably nuanced, complex and dense. Chapter 1 starts with an examination of A/S warfare as practiced in the last years of the First World War which laid the foundations of the A/S philosophy taught at the professional A/S courses in the 1930s. The existing literature was found to be wholly inadequate, and therefore the narrative is based on a reassessment of the primary material to examine the interaction between the U-boats' preference for stealth, and the A/S forces' tactical schemes, centred around convoys, to force the enemy to

[24] Moore, *Royal Navy and Nuclear Weapons*, pp. 46-59 and 184-185; Grove, *Vanguard to Trident*, pp. 3-4.

expose himself to detection and thus destruction. With limited technology, this required a combined "defensive" and "offensive" strategy. The Chapter also shows, contrary to much of the literature, that A/S doctrine did not stagnate in the inter-war years. In particular, convoy remained the central tenet of A/S planning prior the Second World War, though it was also realized that the U-boat could not be defeated without A/S forces taking the offensive. Furthermore, although some scientific advances had been made (particularly asdic echo-location), A/S warfare was still difficult and individual tactics remained inefficient. The inter-war "defensive" and "offensive" holistic doctrine was validated by operations during the first years of the Second World War. Chapter 2 continues the analysis up to 1943 with the emphasis on the difficulty U-boats had in finding their targets and in defending themselves from the growing power of British (and Allied) A/S forces, as well as the complex technical and tactical problem A/S forces had in detecting and attacking U-boats. This explains much about the difficulties experienced by A/S forces when faced with the prospect of countering fast U-boats which the Germans soon began to develop. Together, Chapters 1 and 2 form a backdrop for the remainder of the thesis and demonstrate that there is much mythology in the existing literature, which warps the historiographic view of the Admiralty's late war and early post-war responses.

Chapter 3 shows that, by 1942, the enemy had been forced to cast about for "new" technology to counter A/S aircraft, in particular. The most important device was the schnorkel breathing tube, which, for the first time, allowed the U-boats to operate continuously submerged throughout a war patrol. The British methods of countering these U-boats forms, as it were, the pre-dawn of modern anti-submarine warfare. The task fell primarily on the surface escorts, for the schnorkel, by allowing the U-boats to remain submerged, had largely put A/S aircraft out of business. This chapter also reveals the methods for use of A/S forces were in essence similar to these employed during the First World War. It emphasises the fact that in the shallow waters where the campaign was now fought, anti-submarine conditions remained difficult. The A/S forces (like the U-boats) took some time to become accustomed to the new operating environment and procedures. Coastal Command had the most difficult task, especially in locating these U-boats, whose elusiveness emphasized the vital need for co-ordination of all A/S forces if the schnorkel-fitted U-boats were to be beaten. The prospects, as seen from the Admiralty, of a renewed offensive are discussed. Not only was the immediate problem to defeat the schnorkel-fitted U-boat, but to formulate counters to the enemy's development of new U-boat types, the Type XXI and Walter-boats, with high underwater speed, which could overcome the immobility of the schnorkel boats. The interaction between the technical and tactical elements of A/S warfare against the background of difficult operating conditions has not been adequately explored in earlier studies.

The problem of dealing with the fast U-boats – the dawn of modern A/S warfare – and the Royal Navy's comprehensive plans to deal with the threat are examined in Chapter 4. The Admiralty's rapid and flexible response was based on wide consultation of various staff departments and operational headquarters. The theoretical tactical measures were tried at sea with the modified, high-speed British submarine, *Seraph*. This boat, along with other conversions, was subsequently used for training of A/S escort groups in the tactical procedures that had been developed from evaluations at sea and on the shore-side tactical tables. Further trials were planned with Type XXIs captured at the end of the war to confirm this work, but these were all cancelled, leaving the British with no first-hand experience of operations against fast U-boats. Much of the material presented here is new or substantially revises previously published work.

Immediately after the cessation of hostilities, the Admiralty departments dealing with A/S matters were reorganized and the resultant new directorate set about a preliminary review of A/S policy for the post-war era, which forms a substantial part of Chapter 5. It was assumed that the wartime Type XXI threat would now become the benchmark of the Soviet maritime challenge. The A/S review concluded that future plans should be cast as short-term up to 1950 and long-term problems thereafter. The threat was not seen in specific numerical terms and was viewed in a generic form, based on the continuing assessment of the Type XXI U-boat capability. Drawing on wartime assessments, with additional information provided from captured German documents, the Type XXIs were seen individually as potentially dangerous, though they would have considerable difficulties in locating targets and concentrating for an cooperative attack. Air reconnaissance in support of submarine operations was seen as crucial. These assumptions formed the basis of the first tranche of doctrine papers produced in 1946-47 and to ensure that these assessments were translated into forward policy initiatives, it was seen as vital for A/S warfare to be kept in the forefront of Admiralty, and Air Ministry, activity. To this end, the Joint Sea/Air Warfare Committee (SAWC) was formed, which then became the conduit for the doctrine papers produced (under the Admiralty's leadership) from 1946 onwards. These papers reiterated the combination of defensive and offensive measures, that had proved so successful during the war, and drew in large measure on the experience of those operations, even though now applied to a different threat.

Chapter 6 traces the subsequent production of the, mainly technical, Admiralty papers on the problems of anti-submarine warfare and their proposed remedies. These remedies included requirements for improved A/S equipment and also outlined the history of the anti-submarine campaigns since the First World War. The difficult problems of locating submerged submarines, particularly before they could attack, emphasized the value of more offensive, independent operations, known as "attack-at-source". The Joint Anti-Submarine School, which had been formed to perpetuate the wartime training and trials system, also provided a detailed assessment of offensive and defensive tactical measures to deal with the fast submarine. At a more detailed level, the first exercises with a fast submarine was carried out in early 1948. These were not wholly encouraging. Overlaying these detailed tactical questions was a wider debate over A/S policy which is examined in Chapter 7. This is followed by an analysis of the concurrent development of the second series of doctrine papers, which were less philosophical and more procedural, than their predecessors. These (once more) formalized the use of convoy and, in parallel, the need for supporting operations and, where intelligence was available, independent hunting offensives, together with the idea of attack-at-source. As these papers were being drafted in 1948, the Royal Navy was carrying out a year-long series of exercises with a number of fast submarines. These confirmed, as expected, that success was possible when the submarine was travelling at speeds up to 12 knots but that above this speed A/S performance deteriorated substantially. The results corroborated wartime predictions and confirmed the need for improved A/S technology. At this time aircraft capability was showing signs of some recovery, though much still had to be done. Submarines themselves also became anti-submarine vessels, a role which was formalized in 1948. These trials were carried out against a background of a hardening political and military threat from the Soviet Union and the more obvious entry into the Cold War. Over the year which followed, a series of sea exercises did little to further the understanding of the A/S problem against fast submarines, largely due to the continuing lack of these vessels. A wider analysis of A/S warfare was undertaken in a substantial conference, known as Exercise "Trident" in 1949, which confirmed the British thinking of the close relationship between defensive and offensive A/S operations. This was an aspect ill understood by the Admiralty's historians, which has led to misunderstanding ever since of the Royal Navy's anti-submarine philosophy.

These last three Chapters provide a wholly fresh interpretation of the Admiralty's performance and show that it remained a vibrant organisation. They lead to the Conclusion which summarises the arguments that have already been presented chronologically. It does this by taking a crosswise look through the historical prism, to examine the main themes which have emerged from the thesis. These are: an examination of the nature of anti-submarine warfare and the pursuit of realism in peacetime exercises and trials; an examination of the tactical and technological dynamic stretching over the period 1917-49; an examination of the role of tactical adaptation and the nature of the threat; and, finally, an examination of the symbiotic relationship between the "defensive" and "offensive" in A/S warfare. This last theme – the holistic nature of anti-submarine warfare – provides a new interpretation of not only how the Royal Navy planned to defeat a future submarine attack but also how the doctrine was derived.

Chapter 1: Echoes from the Past, 1917-1940

British Anti-Submarine Warfare, 1917-1940

The U-boat of the First World War relied on surface travel for tactical mobility and for searching for its targets, where using their diesel engines they could achieve 18½ knots in good conditions. They would submerge when threatened by anti-submarine forces or, sometimes, in rough weather. Once underwater, the U-boats relied on their batteries and electric motors for propulsion, which gave them a top speed of about 8½-9½ knots but only for an hour. At, say 3½ knots, however, the U-boat's underwater endurance was about 24-hours. Charging the batteries could only be done on the surface when the diesel engines could be run, so these boats were in every sense "submersibles".[25] While submerged the U-boat's range of vision through the periscope was restricted. The type and rough course of a victim could be distinguished at about 6 or 7 miles (in reasonable visibility by day) but this required a considerable exposure of the periscope.[26] The periscope was, of course, normally used only intermittently. It is not surprising, therefore, as the Naval Intelligence Division (NID) noted, U-boats preferred to remain on the surface, unless forced to dive by anti-submarine (A/S) patrols. On the surface their visual horizon was much extended, they could keep their batteries fully charged, and they were able to manoeuvre into an attacking position ahead of a convoy before diving to attack unseen. The search was considerably extended when two U-boats operated in concert, spread at right-angles to the convoy's track. Such tactics had been noted, although there was no positive evidence of greater numbers working together. With the U-boats widely spread, they had to rely on W/T for passing sighting information, though, even with this advantage, it was not supposed that U-boats could easily deliver simultaneous attacks. The disadvantage of the method was that the British were able to intercept the radio transmissions, and by applying direction-finding (D/F) techniques, warn the convoy of a U-boat in its vicinity. The shore authority (especially when the enemy's signals were decrypted) might also be able to direct an A/S patrol vessel to the U-boat's rough location.

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[25] 'German Navy (Submarines),' CB1182S, [NID], April 1918, AL, pp. 35 and 40.
[26] 'Remarks on Submarine Warfare,' Operations Division, CB0259, January 1917, AL, p. 4.

The U-boat made frequent use of her periscope to assess the relative movement of her target during the final dived approach. Inside about two miles she would be wary of over-exposing her periscope, for fear of it being seen by an escort and the U-boat counter-attacked. The ideal submerged torpedo attack was aimed at a specific ship in the convoy at a range of 500-1,000 yards.[27] With her restricted underwater endurance, a U-boat could only get into a firing position from a relatively narrow angle ahead of the convoy. If the initial sighting was made on the beam or quarter of the convoy, the U-boat had to race on the surface around the convoy until she gained a position ahead of the convoy where she could dive to make a covert final approach. The further ahead she was, the further off the convoy's track the U-boat could afford to be. Subject to the restricted underwater speed and endurance of the U-boat, she could therefore start from positions within what were known as "limiting lines of submerged approach" (LLSuA), which for a 7½ knot convoy were angled about 40º off each bow of the convoy. Dived attacks could only be made in daylight, or on nights were there was strong moonlight, for on a dark night, when a U-boat was practically blind, she would at risk of being run down by a convoy. However, the Admiralty's Anti-Submarine Division noted by October 1917, that on moonlit nights submarines would probably operate on the surface with very little buoyancy, which would make them very difficult to see, even as close as 400 yards. When night attacks were made, it was thought unlikely that the U-boat captain would get between the lines of the convoy, for fear of being run down. Ideally, he would fire from the flank, aiming at an individual ship in the convoy. More often attacks were made at long-range from outside a strong escort (and known as "browning" shots fired in the hope of hitting any ship in the convoy).[28] The general concept for convoy escort dispositions was, where possible, a line of escorts, spaced a mile apart, across the front of the convoy at a distance of 600-800 yards. By zig-zagging, these escorts would provide a physical obstruction to U-boats about to fire at close range. Escorts would also be stationed on the flanks and, where sufficient forces were available, one or more were placed astern where they could respond to a torpedoing with a broadcast barrage of depth-charges, as the remainder of the convoy cleared the area. An escort astern was also used to deter a shadowing U-boat by forcing it to submerge as the convoy made an evasive turn just after dusk.[29]

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[27] 'Tactics of Attack,' in Appendix I to 'German Navy (Submarines),' CB1182S, [NID], April 1918, AL p. 88.

[28] 'Remarks on Submarine Tactics against Convoys,' Anti-Submarine Division, Naval Staff, Admiralty, CB620, October 1917, in, 'Convoy Orders, 1917-1919,' AL, pp. 6-8.

[29] 'Mercantile Convoys: General Instructions for Port Convoy Officers, Ocean and Destroyer Escorts, and Commodores of Convoys,' CB648(2), 18 October 1918, ADM 186/40.

Plate 4: Hydrophone Effect

Generation of Bubbles which cause Cavitation at a Destroyer's Propeller at 15 and 32 knots.

'Annual Report of T.A.S. Schools, 1946', Section II, 'Remarks of H.M.S. *Vernon*', Underwater Weapons Department, Admiralty, UW. 05407/47, C.B. 4486, 24 October 1947, ADM 189/66, Figures 12a and 12b.

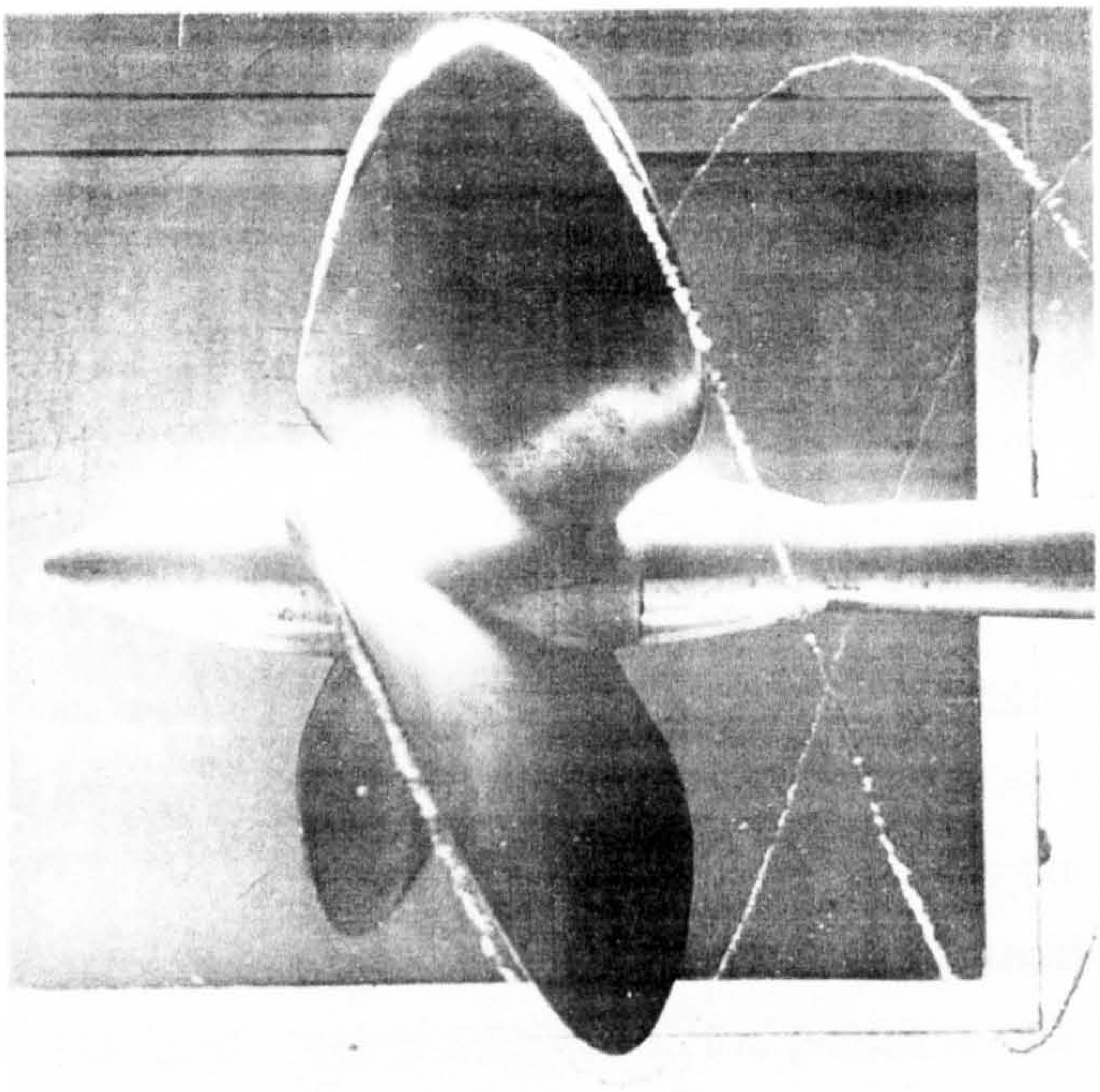

Figure 12a. DESTROYER PROPELLER AT 15 KNOTS

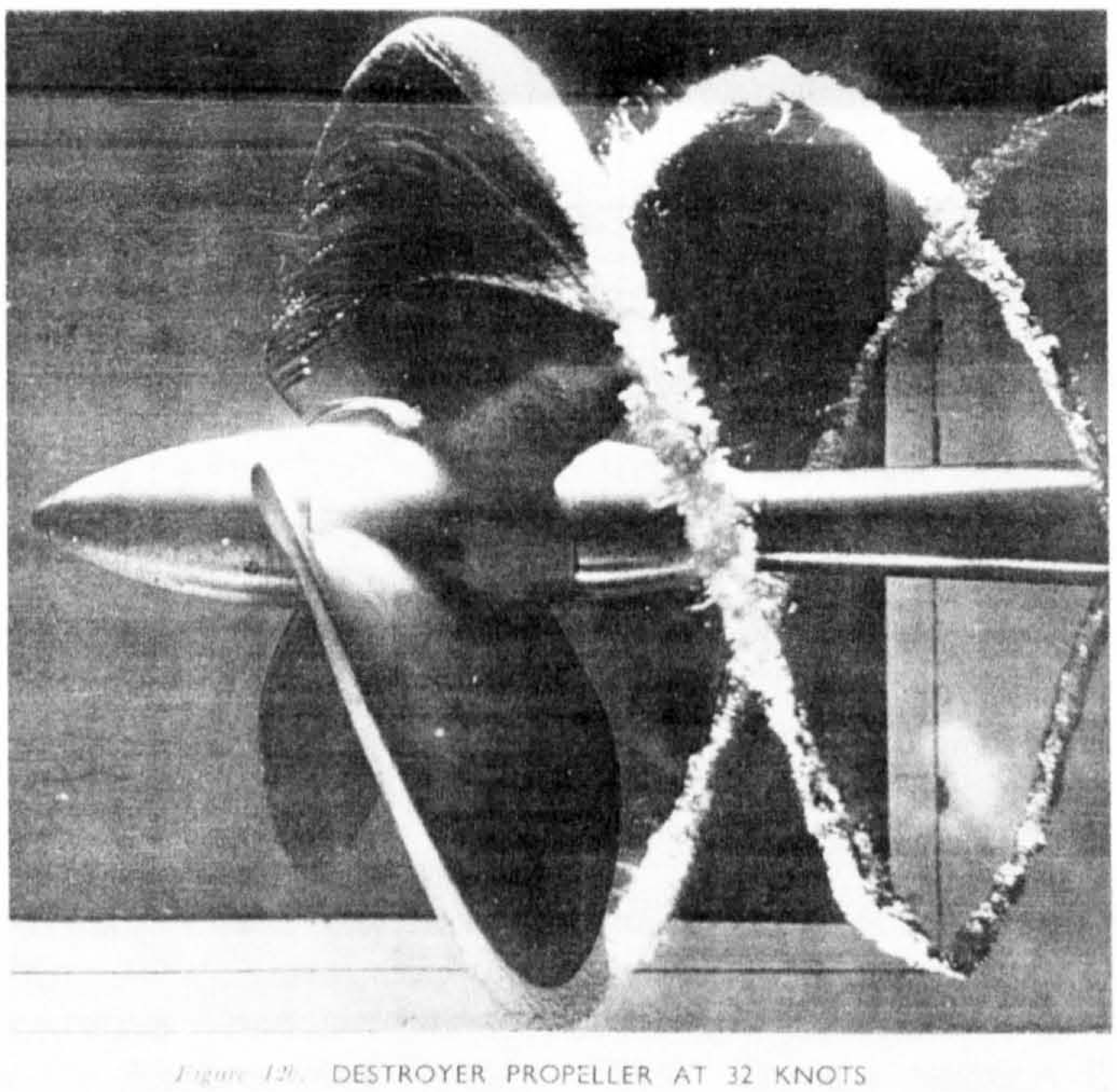

Figure 12b. DESTROYER PROPELLER AT 32 KNOTS

A/S escorts fitted with hydrophones were able to listen for the Hydrophone Effect (HE) from the U-boat's propellers, principally caused by the collapse of the cavitation bubbles created by a rapidly spinning propeller, and, to a lesser extent, by the noise made by the flow of water past the hull and from internal machinery {*Plate 4*}.[30] Listening in the vicinity of surface ships was unproductive, since their HE was likely to drown any noise from the U-boat. When a convoy was attacked, escorts had no means of detecting submerged submarines other than by sighting their periscopes, the trail of oil often left by U-boats, or the water disturbance from a torpedo's discharge and subsequent track.[31] But given a sighting, retaliation could be instant on the part of the escort, and had to be if they were to stand any chance of getting a kill because the U-boat would inevitably move away from its last reported, or datum, position. Depending on the depth of water, the U-boat would either go deep at slow speed, or rest on the bottom, to avoid A/S forces hunting them with hydrophones.[32] These blind barrage attacks by the escorts would not be improved until the introduction of the technique of transmitting and receiving a beam of "supersonic" sound pulses from an underwater acoustic projector (known as the transducer or oscillator). This equipment was known in Britain as "Asdic", and "Sonar" in America {*Plate 5*}. This seemed the most promising device of several being experimented with. When the pulses struck the hull of a U-boat an echo was returned. By timing the interval between the transmission and reception of the sound, an accurate range could be calculated, and by noting the direction of the oscillator, a rough bearing was achieved. Experiments with this method had been carried out since the middle of 1917, but it was only towards the war's end, that seven RN ships were fitted with this gear. In the meantime, several A/S ships working as a team, would lay a blind barrage of depth-charges over the suspected position of the U-boat.[33] Initially, escorts were equipped with only four depth-charges, though this outfit was later increased, with individual vessels carrying 30 depth-charges. Up to 40 depth-charges were expended by hunting groups against individual submarines. Escorts were also used on "extended patrols" at, say, eleven miles, specifically designed to interfere with U-boats on the surface trying to overhaul the convoy. With their greater range of

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[30] Robert J. Urick, *Principles of Underwater Sound*, 3rd edn. (California: Peninsula Publishing, 1983), p. 334.

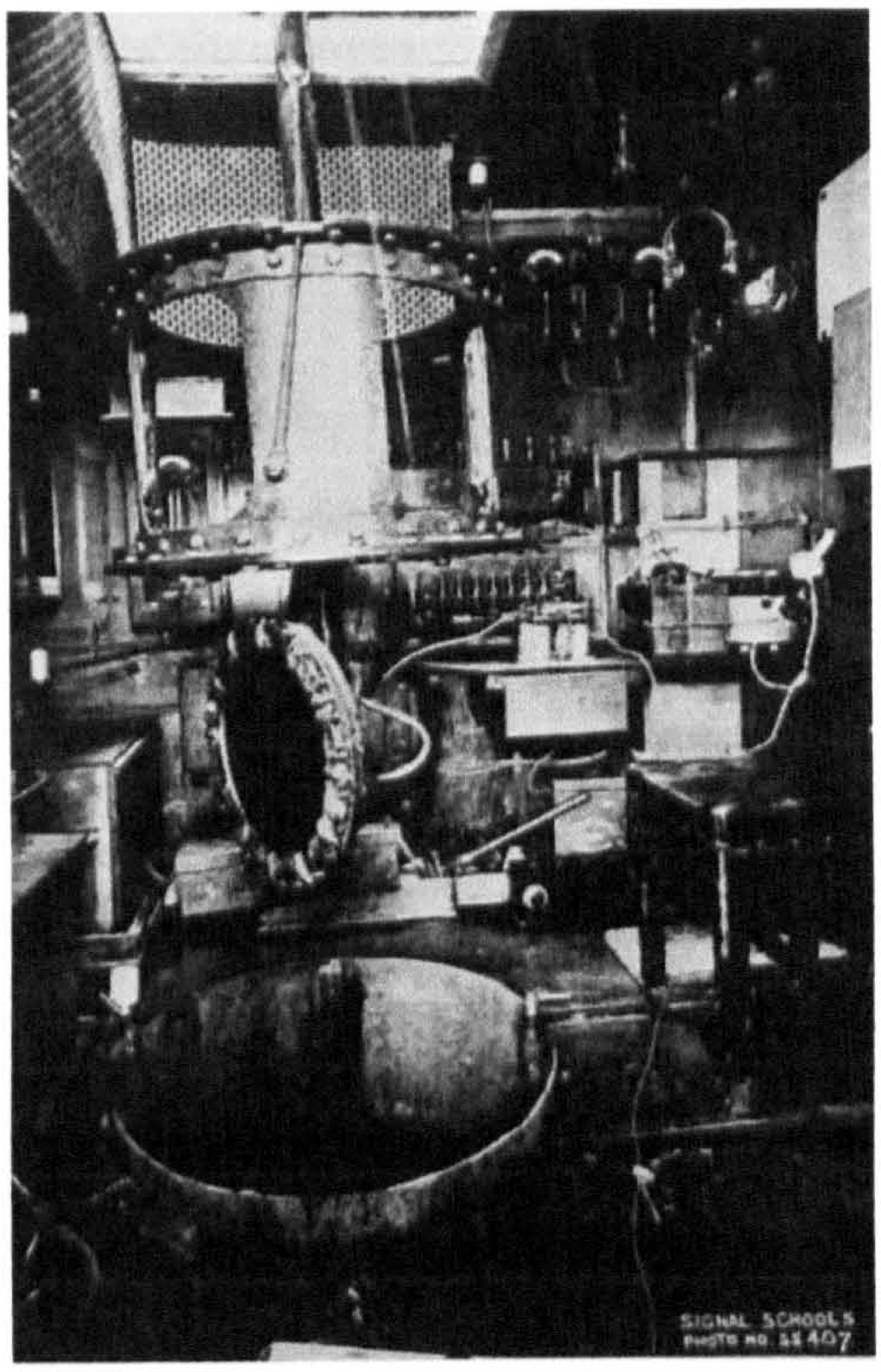
[31] 'Remarks on Submarine Tactics against Convoys, Protection of a Convoy by Extended Patrols, Instructions for Escorts and Patrols, 1919,' Convoy Section Division, Naval Staff, CB648(2)A, 30 April 1919, in, 'Convoy Orders, 1917-1919,' AL, p. 19.

[32] 'Procedure when Hunted with Hydrophones,' in Appendix II to 'German Navy (Submarines),' CB1182S, [NID], April 1918, AL, p. 91.

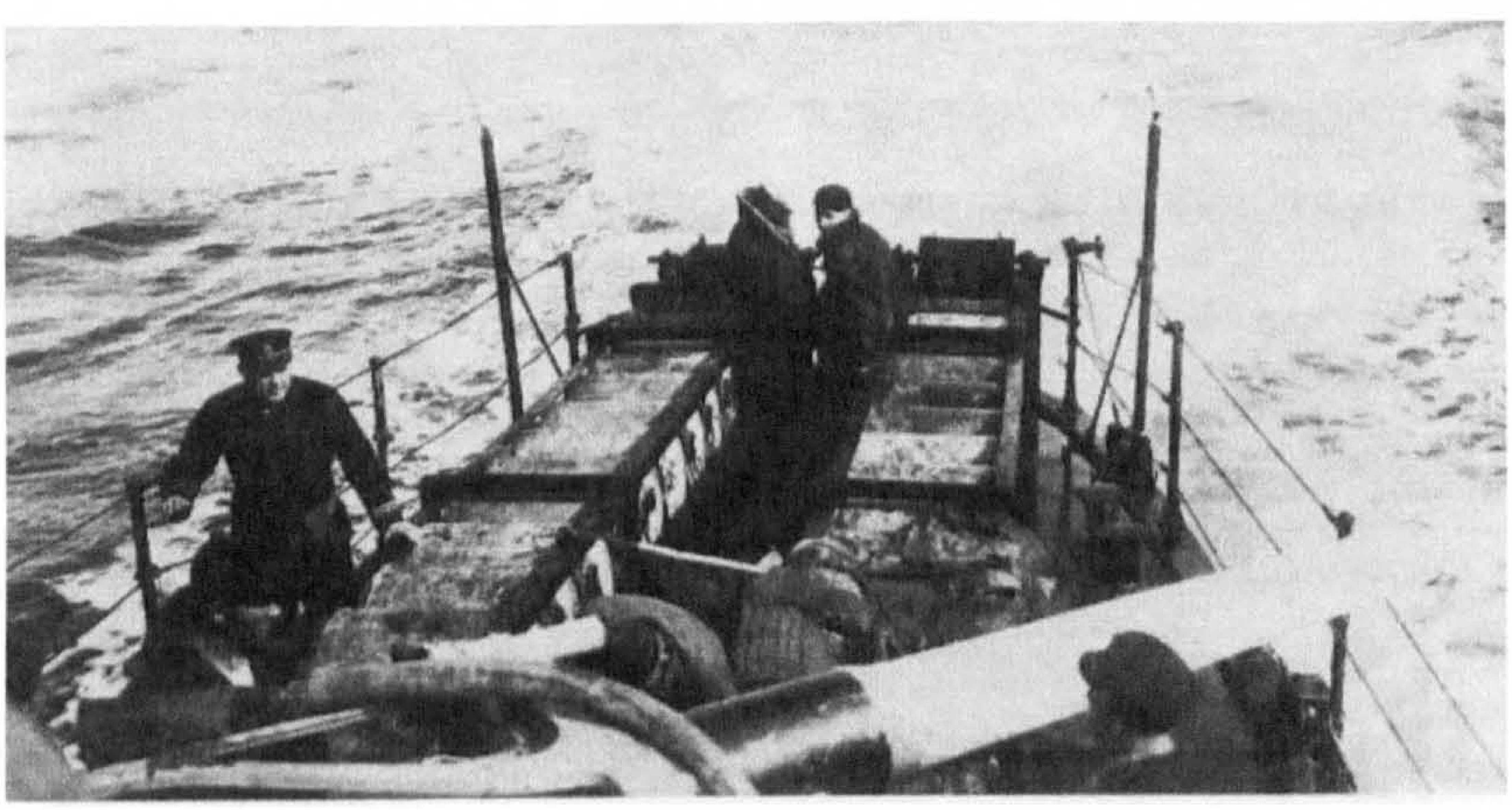
[33] 'Methods Recommended for Carrying out Searches for Hostile Submarines,' CB1238, October 1916, ADM 186/373.

Plate 5: Asdic Oscillator and Depth-Charges

(Admiralty TH9, Fig. 4 and Messimer, pp. 112-113)



Early Asdic Type 122, 1919-1921, showing the oscillator retracted



Depth-Charges

vision and speed, aircraft often replaced surface escorts in this role.[34] Experiments were made with the fitting of searchlights and parachute flares to aircraft in order to detect U-boats on the surface at night. These searchlights were, however, the primary means of detection (not of final attack, as with the later development of the Leigh Light in WWII). Use of the light, therefore, was more likely to warn the U-boat, which could dive before the aircraft had any chance of making contact. The lethality of aircraft attacks, whether by night or day, left much to be desired.[35] Although attacks on convoys had occurred when aircraft were present, U-boat operations were seriously hampered by the constant fear of being sighted by aircraft, for apart from the U-boat, or its periscope being seen, the tracks of its torpedoes were clearly visible from the air. With their low underwater mobility, the U-boats might not be able to get away from the tell-tale beginning of the track before surface escorts arrived to counter-attack. As a result U-boats refrained from attacking convoys with air escort.

The Admiralty's small Historical Section had only been able to narrate the first six months of the main German First World War unrestricted U-boat campaign by 1939. Nevertheless, they noted that defeat by the U-boat was averted principally by the introduction of convoy. It was expected that delays due to convoy assembly, and sailing at the speed of the slowest ships, would reduce the carrying capacity by 12 to 20%. However, '...if the situation was serious enough to require a convoy system,' the Admiralty realized, after the war, 'no reduction in carrying capacity might be involved, compared with other methods of trade protection.'[36] Once the decision to institute convoy had been made, its implementation was delayed by administrative difficulties. By July 1917, 90% of the losses continued amongst independent shipping, although gradually the "...proportion of ships in convoy was increased until practically the whole of the traffic was included."[37] One advantage of convoy that was immediately obvious was that ships in convoy '...could be kept in touch with the latest intelligence.'[38] Both the Official and Staff Histories wondered whether the efficacy of convoy lay '...rather in its power of evasion and its greater power of control than in its power of actual

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[34] 'Remarks on Protection of a Convoy by Extended Patrols,' Anti-Submarine Division, Naval Staff, Admiralty, CB680, November 1917, in, 'Convoy Orders, 1917-1919,' AL.
[35] 'Employment of Aeroplanes for Anti-Submarine Work,' Colonel Williamson, Commanding No. 18 Group, RAF, 14 August 1918, AIR 1/642/17/122/252.
[36] Martin Doughty, *Merchant Shipping and War: A Study in Defence Planning in Twentieth-Century Britain* (London: Royal Historical Society, 1982), p. 47.
[37] Quoted in, 'The Defeat of the Enemy Attack on Shipping, 1939-1945: A Study of Policy and Operations, Vol. 1B (Plans and Tables),' Historical Section, Admiralty, BR1736(51)1B, [CB3304(1B)], 16 April 1957, ADM 234/579, p. 5.
[38] 'Home Waters – Part IX, 1 May 1917 to 31 July 1917,' DTSD, Naval Staff Monographs (Historical) – Volume XIX, Monograph No. 35, CB917R, [OU 5528(H)], August 1939, NHB, pp. 241-245.

protection by escort?'[39] The imposition of convoy faced the U-boats with a conundrum. By concentrating the shipping into a small area, convoy made it more difficult for the U-boats to find their targets. This was accentuated in the open ocean, where individual convoy routes could be widely separated, and even if the U-boat made a sighting, getting into position to attack without being sighted himself was difficult. Yet if the enemy moved inshore, where convoys would be easier to find, the U-boats would be faced with heavy air and surface patrols, which forced them to operate submerged for considerable periods and thereby lose their mobility and search capability. These patrols, especially those by hydrophone-fitted trawlers, would also reinforce convoy escorts as they passed through the patrol areas. At least some officers considered that these operations should be combined with '...bold measures to strike at the U-boats at source.'[40] Although evasion by convoys was the priority, it was still the convoys that brought about more actions between the contending forces than any other cause. Overall, about 250 vessels were employed directly on convoy work, and a further 500 were intermittently on convoy duties, escort or support work. These vessels represented about 15% of the ships in commission in the Royal Navy.

These lessons were emphasized in post-war histories and staff papers. The inter-war years have been portrayed as a period of stagnation in A/S development, both tactically and technically. However, recent research has begun to prove that this was not the case, especially after 1932 when British A/S policy was reviewed. During this period, Germany was not seen as the major threat to British trade. That would come later with her development of ocean raiders and finally U-boats.[41] At the detailed tactical level, attention was paid to increasing the weight of depth-charge attacks to make them more effective. By 1935 it was also recognised that if aircraft were to be effective U-boat killers, they would have to be armed with depth-charges. However the post-war Naval Staff History claimed that, as late as 1937, the Admiralty had had no intention of introducing

> ...A/S bombs larger than 100 lb into the Naval Service, since it is considered that a stick of 100 lb bombs is far more likely to sink or damage a submerged submarine than an equal weight of larger bombs....[42]

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[39] 'Home Waters – Part VIII, December 1916 to April 1917,' DTSD, Naval Staff Monographs (Historical) – Volume XVIII, Monograph No. 34, CB917Q, [OU 5528(G)], May 1933, NHB, p. 471.
[40] Maiolo, *The Royal Navy and Nazi Germany*, p. 126.
[41] The narrative which follows is, in part, drawn from the many issues of 'Progress in Torpedo, Mining, Anti-Submarine Measures, and Chemical Warfare Defence,' and 'Progress in Tactics', listed in the bibliography.
[42] 'The Development of British Naval Aviation, 1919-1945,' Naval Staff History, Second World War, Vol. I, CB3307(1), BR1936(53)(1), 14 July 1954, NHB, p. 89.

The key here seems to be the emphasis on attacks on submerged submarines. The aircraft of the inter-war period were all slow and were only able to carry relatively small bomb-loads, except for Royal Air Force (RAF) Sunderland flying-boats, itself a slow aircraft. Speed was important to convert a sighting into an effective attack, otherwise an aircraft would not be able to attack before a submarine had submerged for long enough to make the aiming point uncertain. It was thought that there was a greater chance of one bomb bursting close to the submarine if a large stick straddled the aiming point. There seem to have been no rigorous tests of the A/S bombs at sea, which might have exposed the poor effectiveness, either when bursting close to a submerged target or even from a direct hit. Attacks by escorts could, however, be deadly, but these too had to be started as soon as possible after contact was gained, normally without waiting for a consort to complete the hunting unit. This was designed to throw the U-boat onto the defensive, to avoid it being able to complete an accurate torpedo shot. Attacks were then to continue with two ships co-operating until the U-boat was destroyed, if this was considered to be expedient. It was recognised at the time that lessons drawn from exercises had to be treated with some caution. It was difficult to divert merchant ships from trade, so convoy exercises had to use naval and auxiliary vessels acting as a convoy. The Admiralty repeatedly noted that the results were also devalued by artificialities imposed by peacetime safety rules, and the desire to get maximum training benefit, which lead to an unrealistic number of A/S units being involved during actions. The analysis of sea exercises was compared with the results from strategic board games at the War College at Greenwich.

Convoys and Striking Forces

The central role of convoy was firmly established both theoretically and in exercises, though the threat from U-boats was not the only, nor even the main, threat. Combined attacks by surface raiders and U-boats was seen as the critical threat, and was known to be a tactic being explored by the Germans.[43] If British heavy ships were required to be part of the escort, convoys would be sailed infrequently and may have to be large, varying between 40 and 90 ships. And as the inter-war years passed, the Admiralty also had to consider the increasing threat of air attack on convoys. Here the focus will be on measures adopted to counter the U-boat, though it was not treated in isolation by the Admiralty during the 1930s. Britain's geographic position *vis-à-vis* Germany forced commerce raiders to make long, hazardous passages to their hunting

[43] Janet M. Manson, *Diplomatic Ramifications of Unrestricted Submarine Warfare, 1939-1941* (London: Greenwood Press, 1990), p. 109.

grounds. The Scandinavian convoys of the First World War showed the danger of an enemy able to sortie from the flank of a convoy route (as the German possession of the Biscay ports was to demonstrate again in the Second War). Principal among the A/S measures was that evasion was the best defence for convoys, particularly if the enemy adopted unrestricted U-boat warfare from the outset. Of course, diversion of a convoy had its limits, if both elements of the "safe and timely arrival" dictum were to be met. From wartime experience, and peacetime exercises, it was

> ...not envisaged that the escorting vessels will be able to prevent a submarine attacking the convoy, but it is hoped that they will be able to destroy the submarine after it has made its attack.

Yet, while a successful defence might be the primary consideration, '...in general,' it was thought, 'the most certain means of obtaining security from enemy submarines is by carrying out a vigorous offensive against them.' Furthermore,

> The moral effect of early success against enemy submarines is likely to militate heavily against the value of his subsequent operations. It is, therefore, of great importance that organisation and training should be such as will allow of the full development of offensive A/S measures immediately on the outbreak of war.[44]

Such protestations were not merely the product of bravado, or an overly optimistic view of the technical progress in asdic development. During the 1930s (when Burnett, Ormsby and Mosse were taking their professional A/S courses) although asdic made significant advances in operational capability, its limitations became evident at the most senior levels of the Royal Navy.[45] A U-boat could be detected out to 6,000 yards, though a more realistic working range was about 2,000-3,000 yards, and once detected its position was known to within 2° in bearing and 25 yards in range. Although once in contact, the chances of continuing to hold the echo were reasonably assured. However, gaining initial detection was by no means certain, especially when water condition were difficult (such as during rough weather, or as a result of unwanted bottom echoes).[46]

Up to the mid-1930s the practice was to station the few A/S ships available for escort on the quarters or astern, where they were best positioned to pounce on a U-

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[44] 'Progress in Torpedo, Mining, Anti-Submarine Measures, and Chemical Warfare Defence, 1932,' CB3002/32, 1933, ADM 186/500, p. 34.

[45] Joseph Maiolo, 'Deception and Intelligence Failure: Anglo-German Preparations for U-boat Warfare in the 1930s,' Paper delivered at the Military History Seminar, King's College, London, 23 February 1999, pp. 15-16; 'Report on Methods of Submarine Location (Draft notes for reply to 1st Sea Lord enquiry dated October 1929),' [A.B. Woods, Admiralty Research Laboratory], 9 November 1929, and B.S. Smith, HMS *Osprey*, to Director, Scientific Research & Experimental Department, Admiralty, 14 August 1929, ADM 218/273. The latter papers are reproduced verbatim at Appendix 2.

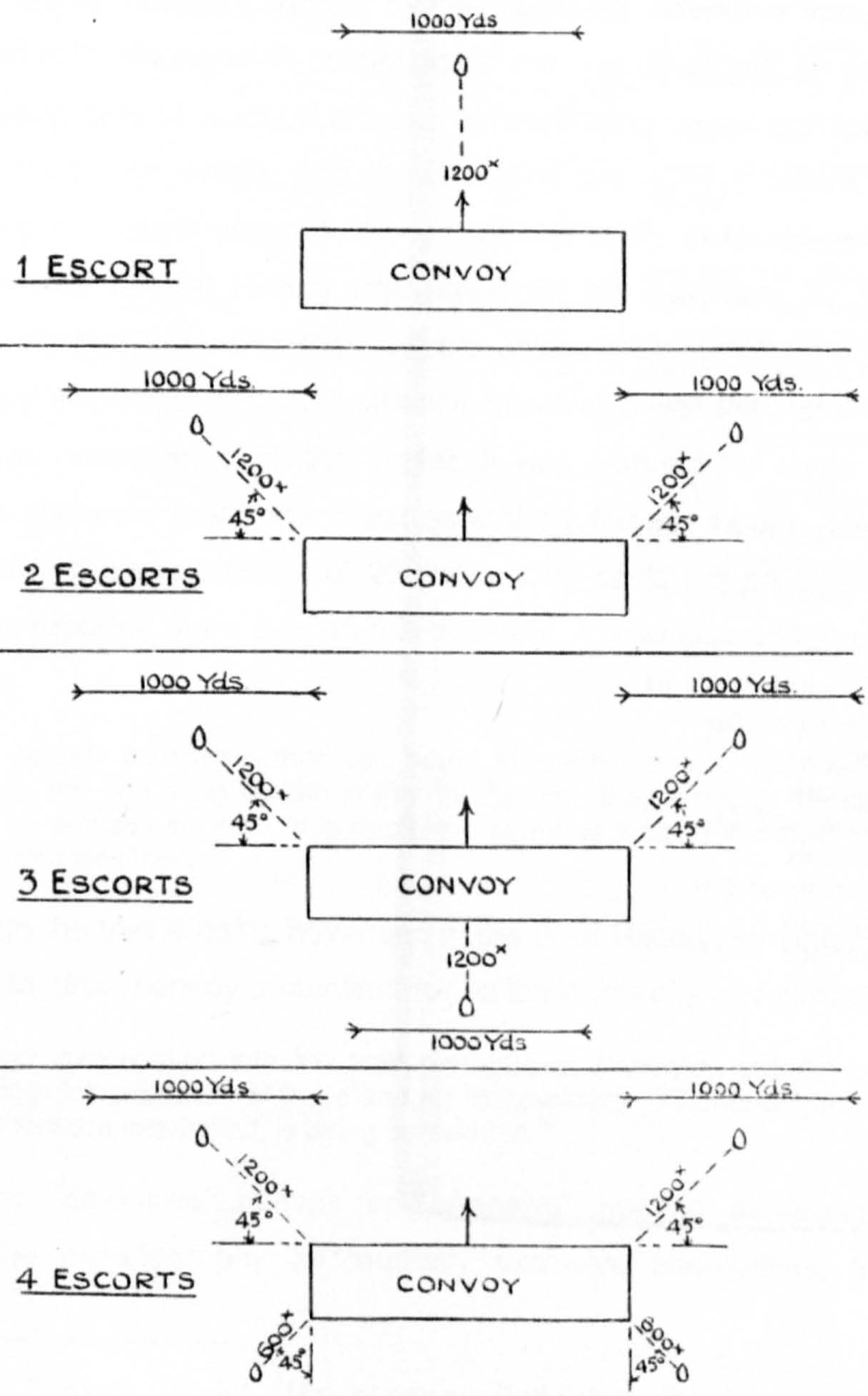
[46] 'Defence against Submarine Attack,' CID Paper 1318-B [Extract], March 1937, ADM 199/2365.

Plate 6: Escort Dispositions, 1938

('Progress in Tactics, 1938,' Tactical Division, CB 3016/38 (BR 1876/38), July 1938, Admiralty Library.)

262. The diagram shows the new dispositions for convoy escorts which will be included in the Mercantile Convoy Instructions on revision.

In the case of a submarine which has attacked the convoy, information is required whether these dispositions are satisfactory in affording the best chance of destroying the submarine.



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boat which had attacked the convoy {*Plate 6*}. Now, with increasing numbers of asdic-fitted escorts it was planned, initially, to fill the stations on the bows of the convoy, where they could hopefully prevent or deter the U-boat from getting into a good firing position. As more escort vessels became available, so the quarter and stern stations were filled. However, with the emphasis now on stationing ships ahead, the Admiralty worried that a U-boat which succeeded in making an attack might then escape destruction. Although the dense asdic screens provided for the Fleet at sea, were able to detect over two-thirds of submarines in exercises, it was realized that such performance would not be mirrored by the relatively sparse coverage afforded to wartime convoys.[47] Investigation continued on the use of aircraft on extended patrols around a convoy, both to warn off U-boats concentrating on the surface ahead (which the convoy might then avoid), and those trailing the convoy astern. Defence of a convoy was by no means assured, though the Admiralty were aware of the German judgement in their Official History (translated for the Admiralty by 1937) over the difficulty U-boats had in closing their targets unless they remained on the surface.[48] Thus to prevent the weight of U-boat attack increasing, it was felt that a spirited attrition of U-boats was necessary from the outset. It was planned for some groups of A/S vessels to be stationed round the coast as striking forces, though it was recognised that, even with A/S ships capable of 20 knots, they could not be expected to reliably detect U-boats reported more than 10 miles distant. A later Naval Staff History later put it another way:

> ...if A/S vessels take more than two hours to reach the reported position of the submarine, the one thing certain is that by the time they arrive at the spot the U-boat will be somewhere else. It is much the same as looking in a dark room for a black cat that isn't there.[49]

But unlike the thesis being advanced in the Staff History, striking forces were not an alternative to direct convoy protection, for as the Admiralty had already noted

> A thorough investigation into the best methods of employing patrol vessels and aircraft, both for protection of trade and for independent A/S operations, which to a certain extent are interlinked, is being carried out.[50]

Instead of the "defensive" convoy or "offensive" hunting strategies, traditionally depicted in the historiography as mutually exclusive alternatives, they are here

[47] 'Progress in Torpedo, Mining, Minesweeping Anti-Submarine Measures and Chemical Warfare Defence, 1937,' CB3002/37, 1937, ADM 186/541, p. 33.
[48] DNI, to Admiralty Librarian, 10 June 1937, and, 'The Naval War, 1914-1918, Submarine War on Commerce' German Official History, Vol. III, Pt. 1, CH. 1-12, AL, pp. 118-119.
[49] 'Home Waters and the Atlantic, Volume I, September 1939 – 8 April 1940,' Naval Staff History, Second World War, CB3301(1), 31 December 1954, NHB, p. 71.
[50] 'Progress in Tactics, 1937,' Tactical Division, CB3016/37, December 1937, AL, p. 115.

expressed as a hypostatic relationship, and this forms a major thematic strand of this thesis. It was a dual policy, which was criticised by subsequent historians.[51] This, it seems, was the philosophy that formed the basis for teaching on the three-and-a-half month long anti-submarine specialist course at HMS *Osprey* during the 1930s which produced many of the officers who rose to prominence during the Battle of the Atlantic and in staff appointments after the war. The course also taught the specialists how difficult A/S warfare could be and how easy it was to miss a submarine. One of these officers, (then) Lieutenant C.D. Howard-Johnston, remembered

> The ordinary U-boat had a silent speed of about 1½ knots. At this speed there was NO hydrophone effect and no sure means of classification if the U-boat laid low. As an A/S Specialist (1930) I knew only too well that a stationary S/M often was a very bad echo target. But once the S/M revved up there was a roar in the water.[52]

These lessons were to become significant towards the end of the coming war. Furthermore, the Admiralty noted that all U-boats should be considered as potential minelayers. Convoy was to prove to be a weapon against the mine itself, because it allowed minesweeping to be co-ordinated with shipping movements to best advantage. However, the U-boat culprit would never have to come near the convoy escorts and therefore stood little risk of destruction.

The Naval Staff History later claimed that the Admiralty, when comparing the loss of carrying power in war due to convoy, failed to take account of the '...crippling delays experienced in war-time by the hold up and routeing of independently routed ships.'[53] But, Captain T.S.V. Phillips, Director of Plans (D of P), drawing on a Ministry of Shipping report after the First World War, argued in a Memorandum of early 1938, that

> ...it is open to doubt whether the delays due to convoy will be any greater than those caused by evasive routeing and shipping being afraid to sail on account of real or imagined dangers. ...Moreover, if, as seems probable, losses in convoy are considerably less than losses in independent sailings, then the number of ships available to carry cargoes will remain greater under a convoy system.[54]

The point was concurred in at the highest level in the Admiralty, and the memorandum despatched to all the Commanders-in-Chief, and enshrined in the manual on the protection of shipping issued in early 1939.[55] Phillips also noted that not only the shipping industry, but '...the nation as a whole is "convoy minded".' The sinking of SS *Endymion* off the coast of Spain in January 1938 provoked questions in the House of

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[51] '[Battle of the Atlantic], Chapter V, September 1939,' [F. Barely and D.W. Waters], n.d., Box PT135, NHB, p. 23.
[52] C.D. Howard-Johnston to J.D. Brown, NHB, 24 February 1980, CCAC, HWJN.
[53] Grove (ed.), *The Defeat of the Enemy Attack on Shipping*, p. 4.
[54] 'Convoy on the Outset of War with Germany,' Plans Division, 19 February 1938, ADM 1/9501.
[55] Minute, Admiral Lord Chatfield, First Sea Lord, 8 March 1938, ADM 1/9501.

Commons and in the press over the use of convoy. So, looking to the future, Phillips considered that

> Any attempt the Admiralty might make in war to avoid going into convoy, however good the reasons might be, would merely be regarded as short-sighted and pig-headed obstruction, which would increase the public agitation for the institution of convoy and weaken the public faith in the Admiralty.[56]

The assumption was that the Germans would embark on unrestricted U-boat warfare from the outset, and thus it was intended to institute convoy immediately on the outbreak of war. This decision was announced in Parliament in 1938.[57] It was generally accepted, Phillips observed, that convoy could not be started until at least six weeks after the outbreak of a war. In the memorandum, Phillips sought ways in which this period could be shortened, by ensuring that the earmarked naval control of shipping officers and commodores of convoys were in place as soon as possible after the commencement of war. Sufficient numbers of cruisers would be available at the outbreak, and armed merchant cruisers soon thereafter, to cope with attacks by enemy surface raiders, though there were not enough heavy ships to escort all convoys if they were needed. Not all the A/S and anti-aircraft (A/A) convoy escorts would be available until the reserve fleet was mobilized, but the shortfall was counterbalanced, because the first homeward bound ocean convoy would not reach the Western Approaches for about two weeks. The Admiralty later noted that some 25% of the available escorts would be required to protect the passage of the Army and RAF to the Continent in the opening weeks of war.[58] As for trade, during the opening weeks many of the ships already at sea would have to complete their passages independently. The question was how could protection be afforded to these ships?

It has been claimed '...that the Royal Navy was as ready to defend against a U-boat campaign as the German navy was ready to mount one.'[59] It was assumed in January 1939, that the enemy would adopt an unrestricted submarine campaign from the outset and the best counter was convoy with surface and air A/S escorts in waters where submarine attack was likely. Although Germany had only 25 U-boats suitable for ocean operations, a force much below that employed during the peak of the 1917-18 U-boat, the Admiralty warned that

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[56] 'Convoy on the Outset of War with Germany,' Plans Division, 19 February 1938, ADM 1/9501.
[57] 'Protection British Shipping in the Vicinity of the British Isles during the first 14 days of an Emergency,' Captain F.R Garside, Assistant D of P, 30 August 1938, in, 'Naval War Memorandum (Germany),' Admiralty, 1937-1939, Case 00244, Vol. II, NHB.
[58] 'Movement of Advanced Air Striking Force and Field Force to France, Plan "W4",' Section IXA, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.
[59] Maiolo, *The Royal Navy and Nazi Germany*, pp. 120-121.

> ...a few highly skilled German U-boat Captains caused a high percentage of our shipping losses and that in 1939 the German submarines will be commanded by peace-time trained and presumably efficient Captains.[60]

Initially, in-bound trade would be ordered to adopt an approximation to the convoy system, with ships rendezvousing in loose groups at selected ocean positions, from where escort groups would accompany them to their destination ports. Ships which were unable to make the rendezvous were to sail independently on wide diversionary routes.[61] The escort groups, when not involved in direct support of trade, would carry out offensive patrols in the shipping areas. This system was needed only until all ships in threatened areas could be brought into convoy and adequate A/S forces became available. Even then, offensive operations were not to be wholly abandoned.

It should not be supposed that the lessons from the First World War, or inter-war exercises, were directly used by those planning future counter-measures, rather the experiences were infused by a process of osmosis.[62] What was well established was a holistic doctrine of defensive and offensive measures, which formed the basis of the new version of the "Anti-Submarine Warfare Manual", issued in February 1939. This Manual confirmed the value of convoy by increasing the difficulty of U-boats in finding targets and, where intelligence was available, of diverting shipping clear of U-boat concentrations. If U-boats were to get into position to attack convoys, they had to move on the surface, where they were vulnerable to detection by wide-ranging aircraft. Even if the aircraft were not able to destroy the U-boats, they could home surface escorts to the location and this, for the enemy, was far more dangerous. Aircraft were to be used to support convoys or Fleet units. The Fleet would normally have sufficient aircraft for inner and outer A/S patrols, though convoys would seldom be supported by enough aircraft to carry out both types of patrol simultaneously. The priority was for an outer patrol to be flown some 15-20 miles ahead of a convoy, where it would cover the area in which U-boats would be moving on the surface to get ahead of the convoy. This plan, proposed by the Admiralty after wide consultation was agreed by Coastal Command.[63]

Convoy also forced U-boats to attack merchant ships where they had to accept the risk of counter-attack by the A/S escort. Although asdic-fitted escorts could not

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60 'Review of the Requirements of Trade Protection,' Section III, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB, p. 11.
61 'Trade Protection – Detailed Arrangements,' Section VII, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB, pp. 49-50.
62 Geoffrey Budd, Telephone Interviews, 23-26 March 2003.
63 [Principles of Anti-Submarine Patrol by Aircraft], J. Lawson, Admiralty, M/NAD.398/37, 31 August 1937, AIR 15/38.

provide an impenetrable screen ahead of convoys, they were better able (than previously) to detect escaping U-boats and exact retribution. The Manual exhorted A/S ships to adopt an aggressive posture, for

> It is evident that the destruction of a submarine reduces the risk to subsequent convoys. Further, enemy submarine morale must be considerably affected by the knowledge that an attack on a convoy is inevitably followed by swift counter-measures.[64]

The formal doctrine was thus heavily centred on defensive measures necessary for the protection of trade and the Fleet, albeit conducted aggressively. Offensive operations were the subject of a draft Memorandum by Captain D.A. Budgen, RN, Director of the Tactical Division (D of TD) in the spring of 1938. The Memorandum made slow progress around the Naval Staff and Commands afloat. There was general agreement with Budgen's proposals that groups of four, or more, asdic-fitted A/S vessels with air support, would be disposed to take advantage of intelligence. Ship-air communications and accuracy of reporting were crucial to the success of the co-operation. However, only a few months before the outbreak of war, the Director of the Naval Air Division noted that:

> The training of the RAF in A/S tactics in conjunction with the A/S School at Portland is proceeding better than heretofore, but much remains to be done. It is hoped that it may be possible to arrange later in the year for FAA aircraft to co-operate with the A/S School in the investigation of A/S tactics.[65]

These were serious limitations, though largely organizational in nature. Where intelligence was sparse, the chances of the A/S group making contact were slight, but where accurate reports were available, or a sighting was within, say, 10 miles of the hunting force, there was a good prospect of the ships gaining contact and being able to prosecute the U-boat.[66] The tactical concepts were incorporated in the formal A/S tactical manual when it was re-issued in 1940. Meanwhile, the Memorandum was broadly welcomed, though Captain V.H. Danckwerts, now D of P, cautioned that

> Although it would clearly be desirable to start a vigorous offensive against enemy submarine on the outbreak of war, the extent to which we can do this is strictly limited by the number of A/S craft which we can afford to keep in commission in peace time.

And to hammer home the point, Danckwerts added that,

> Generally speaking, it is considered that the most profitable and effective method for providing this security with limited forces available in the initial stages, is by

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[64] 'Manual of Anti-Submarine Warfare, 1939,' Tactical Division, CB3044, February 1939, NHB, p. 38.
[65] Minute, DNAD, 15 May 1939, ADM 1/12141.
[66] 'Anti-Submarine Striking Forces, [Revised Form of Draft],' Memorandum by Tactical Division, Naval Staff, June 1938, ADM 1/12141.

> providing escorts for all movements most likely to be menaced by submarine attack.[67]

Realistically, he considered that with all the commitments for direct escort, there would be no A/S craft to form striking forces for some time. When he reviewed the Staff comments, on the employment of striking forces, Budgen wondered whether he might have over-emphasized their tactical importance. But, Budgen added, whether protection was provided by escort of striking forces, it would '...fail unless the personnel have been, firstly, efficiently trained and, secondly, kept efficient by constant practice.'[68]

Wartime Experience

'Except for the first two months of the war, before the convoy system had been fully instituted, there have been no destroyers available for A/S Hunting Forces,' Captain A.G Talbot, Director of Anti-Submarine Warfare (DASW), wrote in February 1940.[69] During these two months, 75% of U-boat attacks had been against independently routed shipping, which had not yet been brought into convoy.[70] Initially, protection for this shipping was provided by Striking Forces, some of them based around aircraft carriers. One of these hunting operations accounted for *U-39*, the first U-boat sunk during the war by three ships of Captain C.S. Daniel's 8th Destroyer Flotilla while escorting *Ark Royal* on an A/S sweep.[71] The carrier had been narrowly missed by the U-boat's torpedoes, having unnecessarily exposed herself while flying off aircraft. One of the other carriers, *Hermes*, had an unexciting time, but a few days later the *Courageous*, also on A/S hunting operations, was attacked in similar circumstances and sunk. The Staff History later concluded that: 'In the light of events there is no doubt that the employment of large aircraft carriers for hunting submarine was a mistake.' However, the History also, rightly noted that:

> At the same time, it is only fair to state that it was no more than a temporary measure intended to cover the period before the full convoy system came into operation. The risk to a hunting carrier was by no means ignored, and the opinions of the Naval staff all emphasised the vital necessity for a full-time, effective A/S screen, especially as a carrier was obliged to maintain a steady course during periods when aircraft were being flown off and on....[72]

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67 Minute, D of P, 22 March 1939, ADM 1/12141.
68 Minute, Captain D.A. Budgen, RN, D of TD, 13 April 1939, ADM 1/12141.
69 'Review of Methods of Dealing with the U-boat Menace,' ADM 1/10468, p. 42.
70 Jürgen Rohwer, *Axis Submarine Successes of World War Two: German, Italian and Japanese Submarine Successes, 1939-1945* (London: Greenhill Books, 1999), pp. 1-5.
71 'Anti-Submarine Operations in North Atlantic, 12 to 16 September 1939,' Pack No. 0556/0, BSR 522/1, NHB.
72 'Home Waters and the Atlantic, Volume I...,' NHB, p. 69.

The loss of *Courageous* on 17 September 1939 has been portrayed as a damning indictment of the Admiralty's offensive policy during the opening months of the war, and the direct reason for its abandonment thereafter, for the other two carriers were recalled on 18 September and took no further part in A/S operations. Yet the draft Naval Staff narrative (which was abandoned) of the Battle of the Atlantic, although criticising the Royal Navy's offensive policies, notes a significantly different reason for the withdrawal of the carriers. This was that after

> ...the *Courageous* was sunk...the Admiralty decided that the *Ark Royal* should no longer be used for hunting submarines as the influx of independent ships had now diminished.[73]

These views were echoed a month after the loss of *Courageous*, as the Naval Staff considered *Hermes*' A/S patrol in the South-West Approaches, during which one U-boat was sighted by aircraft and three contacts gained by the weak force of escorting destroyers, but none led to a kill. The Naval Air and the Anti-Submarine Divisions warned against exaggerating the power of aircraft to locate and destroy U-boats.[74] More significantly, Captain Edelsten, in D of P, was '...of the opinion that, since the institution of convoy, the results expected from the employment of carriers on A/S hunts do not justify the risks involved.' Crucially, Edelsten added, '...our carriers are now urgently required for hunting surface raiders.'[75] It was these reasons, and not simply the loss of *Courageous*, which motivated the withdrawal of the carriers from these offensive operations: for losses were expected and accepted. Moreover, the Admiralty issued further guidance on the use of aircraft carriers in trade protection, following considerable discussion within the Naval Staff during the month following the loss of *Courageous*. The view was not that the carriers had been misused, but that the tactics of their air and surface striking forces had been inadequate, both in locating and destroying U-boats as well as protecting the carrier.[76]

The Home Waters Staff History also claims that the destroyer hunting groups were equally a waste of time and curiously suggests that their successes were more due to chance than design, and the more detailed Staff History on the A/S war wrongly credits some of the U-boat losses to "escorts".[77] A detailed examination of the first two months of the war shows that, of the 7 U-boats sunk, 3 fell victim to mines, one to A/S

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[73] '[Battle of the Atlantic], Chapter V, September 1939,' [F. Barely and D.W. Waters], n.d., Box PT135, NHB, pp. 29-30.
[74] Minute, G.M.B. Langley, for Director of Naval Air Division, 9 October 1939, ADM 199/137.
[75] Minute, J.H. Edelsten, D of P, 25 October 1939, ADM 199/137.
[76] '[Conduct of Aircraft Carriers and Destroyers when Engaged in Anti-Submarine Operations],' S.H. Phillips, Secretary, Admiralty, M.015382/39, 28 November 1939, ADM 199/124.
[77] 'Home Waters and the Atlantic, Volume I...,' NHB, pp. 70-71.

escorts which were shifting from one convoy to another, and the remaining 3 U-boats were destroyed by surface A/S hunting groups. Aircraft, both carrier and land-based, although they made plenty of sightings were unable to convert them into lethal attacks, being too slow and still equipped with the ineffective A/S bomb.[78] Attacks, therefore, remained ineffective until the introduction of the airborne depth-charge, a saga which would benefit from further research. However, right from the start, and with increasing emphasis as the war progressed, considerable weight was placed on the provision of support groups of fast escorts, along with land-based aircraft and escort carriers, either to reinforce convoys or to operate on independent offensive operations.[79] When discussing the relative vulnerability of carriers to conventional weapons, Commander G.A. Titterton, Historical Section, later wrote, that

> ...briefly the position appears to be this. In the last war, between the outbreak of war and VE-day 63 British carriers were commissioned. Of this number, eight were sunk by enemy action; five by U-boat; one by internal explosion, one by warships' gunfire and one (*Hermes*) by aircraft bombs. Several...were damaged and put out of action for some months by bombs.[80]

Long before the creation of the Operational Research Division, every avenue to improve performance was sought, including the setting up of a committee under Vice Admiral T.H. Binney reporting directly to the First Sea Lord. Binney was distanced from actual operations and his Committee was to investigate war problems and generate ideas which might be of use to the Naval Staff. In his first report Binney considered "The Submarine Campaign", and was '...struck by the fact that anti-submarine vessels can only be certain of a kill if they are situated within a very short distance of the reported position of a submarine.' It followed, the Committee concluded

> ...that the best position for anti-submarine vessels is in <u>company</u> with a convoy. ...We recommend that for the present every anti-submarine vessel with sufficiently good sea-keeping qualities should be employed with convoy rather than being dispersed in hunting units when the time factor of reaching the submarine will always make success very doubtful.[81]

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[78] 'The Development of British Naval Aviation, 1919-1945,' Naval Staff History, Second World War, Vol. I, CB3307(1), BR1936(53)(1), 14 July 1954, NHB, p. 92; K.C. Baff, *Maritime is Number Ten: The Sunderland Era* (Privately Published, 1983), p. 35.

[79] W.A.B. Douglas, Roger Sarty, Michael Whitby, *No Higher Purpose: The Official Operational History of the Royal Canadian Navy in the Second World War, 1939-1943*, Vol. II, Part 1 (St. Catherines, Ontario: Vanwell Publishing Limited, 2002), p. 115.

[80] Commander G.A. Titterton, Historical Section, Admiralty, to Squadron Leader Mervyn Mills, AHB, Air Ministry, 29 March 1959, in, 'Selected Convoys: Mediterranean, 1941-42, Revised Battle Summaries, Nos. 18, 32,' Folder, NHB.

[81] 'Vice Admiral Binney's Committee, IDC.2,' Vice Admiral T.H. Binney, Imperial Defence College, 21 September 1939, ADM 205/1. [emphasis supplied]

This, the Naval Staff noted on the report, was '...the principle adopted...' and no further action was needed to amend operational priorities.[82] Binney's comments were selectively quoted by the Naval Staff and Official Historians.[83] At least Roskill noted the Naval Staff's annotation but he failed to comprehend the need for area operations before the full imposition of convoy was possible. Within a few days, Binney's committee was exploring the use of "Q" Ships along with supporting A/S vessels, and a month later was expressing the idea of A/S ship patrols to deter U-boat minelaying operations. By the end of the year, Binney, noting the increased numbers of U-boats likely to appear in the immediate future, concluded that '...there is no possibility of being able to relax our present measures for the A/S offensive.'[84]

Churchill, the First Lord, was also unceasing in his search for offensive operations. One of his schemes expressed in a typical minute to the First Sea Lord in November 1939, read:

> Nothing can be more important in the anti-submarine war than to try to obtain an independent flotilla which could work like a cavalry division on the approaches, without worrying about the traffic or U-boat sinkings, but could systematically search large areas over a wide front. In this war these areas would become untenable to U-boats, and many other advantages would flow from the manoeuvre.[85]

Unmoved, Pound passed the note to Captain A.G. Talbot, the new Director of Anti-Submarine Warfare, asking for his comments in view of his experiences while commanding a striking force. Talbot, an evangelist of offensive operations, replied a couple of days later expressing himself to have always been very much in favour of A/S striking forces, though he stressed that their success relied on adequate intelligence of the U-boat positions. Talbot described the tactics he used. If searching for a surfaced U-boat, his four ships could be spread out and able to cover a front of about 35 miles. Even this made the search of large areas (often as much as 50,000 square miles) problematic. However, if the destroyers could close on a merchant ship being attacked they stood a better chance of gaining contact. He found that, with the relative navigational uncertainties inherent in these operations, that it was better to steam along the D/F bearing than to attempt to close the reported latitude and longitude. Once the U-boat had submerged the search front would be very much reduced, to 6 miles at the

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[82] Pencil margin note in, 'Vice Admiral Binney's Committee, IDC.2,' Vice Admiral T.H. Binney, Imperial Defence College, 21 September 1939, ADM 205/1, p. 2.
[83] 'Home Waters and the Atlantic, Volume I...,' NHB, pp. 70-71; Roskill, *War at Sea*, Vol. I, pp. 134-135.
[84] 'Review of the Situation at Sea, December 1939, Vice Admiral Binney's Committee,' Vice Admiral T.H. Binney, IDC.38, 8 December 1939, ADM 1/9793.
[85] Note, Churchill to First Sea Lord, 20 November 1939, ADM 205/2.

most, and possible less when the number of non-sub contacts was high. Talbot thought that the

> ...key to success in killing a U-boat by this means is for the Striking Force to be able to sight it on the surface. Assuming that this is done and that the U-boat dives when the destroyers are 8 miles away, a minimum of three ships is required to locate her.[86]

Over the winter of 1939-40, Captain J.H. Edelsten, Deputy D of P, and Captain Talbot, DASW, each considered the progress of the A/S campaign and developed ideas for future policy. Edelsten, in a brief but perceptive examination reiterating that the

> ...pre-war A/S plan was to attack U-boats with hunting groups until it became necessary to go into convoy, and then to rely mainly on attacking them at the convoys themselves, by allocating most of our A/S craft to escort duties.

'This convoys system, augmented by other subsidiary measures,' he observed, 'was sufficient to defeat the U-boat campaign in the last war, and has succeeded in inflicting considerable casualties on the U-boats in this war.' But Edelsten was sure that convoy

> ...will not in itself defeat the U-boat campaign...if the U-boats vary the localities and forms of their attacks to such a degree that we are unable to meet them in all places and against all forms simultaneously.

U-boats, he noted, were already using mines in addition to the torpedo. Mines, of course, could be laid on the convoy routes without the U-boats coming anywhere near the escorts. In the future, Edelsten prophesied the enemy might employ other weapons, including

> ...a wireless controlled torpedo...which can be brought into contact with our ships without serious risk of counter-attack on the submarine herself by our escorting craft.[87]

In addition the U-boats could also vary their geographic areas of operation, probably as far afield as Halifax, Nova Scotia. The number of A/S vessels required to provide security against all such forms of attack in all possible areas was probably far beyond British resources, so, Edelsten concluded,

> ...the U-boat will only be successfully mastered once and for all by offensive measures designed to destroy them regardless of the mission on which they are engaged.[88]

The offensive measures he envisaged were the planned combination of minefields, seabed indicator loops and shore radar sites, that could cue hunting groups of

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[86] Captain A.G. Talbot, Director of Anti-Submarine Warfare, to First Sea Lord, [M.013984/39], 23 November 1939, ADM 205/2.
[87] Minute, Captain J.H. Edelsten, D of P, PD.08182/39, 26 November 1939, ADM 1/10084.
[88] *Ibid.*

destroyers onto transiting U-boats. Radar-fitted aircraft, which were due to start coming into service shortly would also be useful. Edelsten, a logical and incisive thinker, was persuaded that any shift towards more offensive operations needed to be undertaken gradually, and only when the direct protection of convoys by A/S escorts was assured. In this he was supported by others on the Naval Staff.[89] Characteristically, Talbot was broadly in favour of the offensive measures, except for the use of indicator loops in the open sea because large numbers of A/S vessels were required to re-locate a loop contact. These vessels, he thought, would be better employed elsewhere.

At the end of February 1940, Captain Talbot completed his own review for the Naval Staff of the methods of dealing with U-boats, which echoed much of Edelsten's earlier minute.[90] He expected the U-boat commissioning rate would soon accelerate and, therefore, unless sinkings by A/S forces could also be increased, the number of operational U-boats would escalate dangerously. For operations in the Western Approaches, U-boats could best be dealt with by:–

> (a) A continuation of the convoy system coupled with resolute offensive action by the convoy escorts should a ship in convoy be attacked. A U-boat, having once given away her presence, must be hunted even if this leaves the convoy temporarily unescorted; one ship remaining in the vicinity for 24 hours or until relieved.
>
> (b) The provision of a fast A/S Striking Force cruising in the area, operating on intelligence provided by D/F, and air and surface reports of U-boats.[91]

However, as Edelsten had pointed out, the policy of escort of convoy would do little to curb the activities of minelaying U-boats. Taking a leaf from Edelsten's paper, Talbot thought it prudent to assume

> ...that the enemy will intensify not only their mine-laying campaign in Home Waters but also unrestricted warfare, using the torpedo and gun, in waters further afield where there is less likelihood of counter-attack by our A/S forces.[92]

The response to the mine-layer was to try to stop these U-boats reaching their operational areas. The measures considered included the blockade of raw materials, the bombing of submarine building yards and factories, and training establishments (though these measures could not be implemented because of the existing restricted air bombardment policy). Talbot also suggested that it would be profitable to repeatedly mine U-boat training areas and base exits, and use British submarines off German harbours to attack U-boats entering and leaving. He also worried that the enemy might change his tactics, by attacking the escorts, which meant they needed to be more

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[89] Minute, Captain M.J. Mansergh, DTD, 29 December 1939, ADM 199/124.
[90] Minute, Admiral H.M. Burrough, ACNS, 7 March 1940, ADM 1/10468.
[91] 'Review of Methods of Dealing with the U-boat Menace,' ADM 1/10468, p. 31.
[92] *Ibid*, pp. 14-15.

conscious of their own self-protection. In part this was so that escort forces would not be whittled down, for Talbot wanted fast Striking Forces as soon as practicable. Their effectiveness would rest on every effort being made

> ...to improve our supply of information about U-boat sailings. Such information would greatly increase the chances of destroying U-boats before their arrival on their hunting grounds owing to the added incentive to all A/S forces of knowing that a U-boat is on passage.[93]

Air reconnaissance was essential and would be extended at night or in poor visibility by the deployment of radar-fitted aircraft already carrying out trials. Air-sea co-operation in these conditions would be even more difficult and would require considerable practice to perfect. But although exploring these offensive measures, Talbot emphasized several times, the first commitment had to be convoy escort. But, while this might ensure the safe arrival of shipping, it would not defeat the U-boat. The only way to do this, Talbot was sure, was to destroy the U-boats at every opportunity.

Captain C.S. Daniel, now D of P, noted from personal experience, that the use of Striking Forces on a stale scent was a waste of time and wore down personnel and equipment unnecessarily. The trick was to get the ships into close proximity of the U-boat, when asdic could come into its own. Still he was not against the concept and distilled the essence of Talbot's paper into the three constituent, and interrelated, methods of countering the U-boat menace, which was broadly agreed by the First Sea Lord, Admiral Sir Dudley Pound:–

(a) Dealing with them at source.
(b) Restricting their passage to certain areas where small A/S forces can attack effectively.
(c) Making them face destruction when they reach a position to attack their target.[94]

The Admiralty is sometimes seen as espousing a dogmatic approach to A/S warfare that leans heavily towards unproductive offensive operations. In reality, the Admiralty, and the Commands, had formulated a more subtle and flexible doctrine, which was to prove its efficacy throughout the wart and into the post-war years. This does not mean that every avenue was covered. The Royal Navy was presented with night surface attacks by U-boats about one year into the war. It is not evident that this came as a surprise to the Royal Navy. Captain N.A. Prichard a wartime Director of the Anti-Submarine Division thought that

[93] 'Review of Methods of Dealing with the U-boat Menace,' ADM 1/10468, p. 16.
[94] Minute, Captain C.S. Daniel, D of P, 20 March 1940, ADM 1/10468. See annotation on [Captain L.E. Holland], AHO to First Sea Lord, 12 March 1940, ADM 1/10468.

> ...it would have been a "long shot" to have foreseen this method of attack in peace time, though...a few night exercises against submarines on the surface were carried out which were abandoned owing to the danger to the submarine.[95]

One British submariner had gone so far as to champion the night surface attack as an important, but subsidiary, tactic a few months before war broke out.[96] Although experiments had been conducted with flares during the First World War, in reality little could be done to counter these tactics until the widespread introduction of radar.

Overall, the Admiralty's approach was under pinned by a widespread realization that anti-submarine warfare was difficult. For example, Captain R. Kerr, Captain (D) of the highly efficient Second Destroyer Flotilla, highlighted an issue that was a constant concern to the Admiralty and Commands, that '...peacetime restrictions have to be observed which unless properly considered are liable to give false conclusions to A/S vessels and submarines.' By way of illustration, Kerr noted that submarines were often allowed to remain at periscope depth until they had fired a torpedo during Fleet A/S exercises, which '...gives the A/S personnel a wrong impression of how to counter-attack as they are not allowed to go within 1,200 yards of a periscope....' As a result, the submarine's reaction would be unrealistic. Kerr also considered that anti-submarine warfare

> ...is unlike any other form of attack. It is an attempt to sink an invisible enemy by a sense which is not in every day use. A/S efficiency depends on the appreciation of the quality of a sound. It is very much harder to distinguish between two notes of the same pitch played by different instruments, than to appreciate that a note is being struck.[97]

Kerr had been the senior instructor at the A/S specialist school at HMS *Osprey* and also had the benefit of a flotilla of new ships whose training had been rigorously pursued over the previous three years by a keen staff of A/S specialists, including Lieutenant J.P. Mosse.[98] The essential problem was that of differentiating between submarine and non-submarine asdic echoes. 'The Asdic operator,' Kerr wrote, 'has to keep in mind what a submarine echo may sound like under all conditions and so distinguish it from other almost exactly similar sounds.' The difficulty was that '...a sound is very much more difficult to memorise than something that can be seen or felt.' So, to maintain their ephemeral skill, operators required '...frequent practice at sea...in

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95 Draft Minute, DASW, 26 July 1945, ADM 1/17659.
96 'The Offensive Value of the Modern Submarine,' "Salvo" (Lieutenant I.L.M. McGeoch), May 1939, IWM P347, pp. 8-9; 'Exercise "ZL", Combined Fleets, 7-15 March 1935,' in, 'Exercises and Operations 1935,' CB1769/35(1) and (2), September 1937, ADM 186/157, p. 43.
97 'Anti-Submarine Training,' Captain R. Kerr, Captain (D), Second Destroyer Flotilla, [13 June 1939], ADM 205/3. See Appendix 2.
98 'The Evolution of the *Osprey*,' Lieutenant Commander F.M. Mason, Summer 1938 (issued 30 January 1942), P.1009, AL, p. 27.

bad conditions as well as in good.'[99] At the same time other members of the team should rehearse the operation of the asdic range recorder used to indicate the time to fire, while the integration of all the tactical information on the asdic plot needed practice. The environment, therefore, made A/S warfare difficult even without the submarine adopting stealthy anti-escort tactics. These problems would be exacerbated by the later development of submarines capable of high underwater speed.

This Chapter has examined the developmental threads connecting the Royal Navy's experiences in the First World War and in the opening phases of the Second World War. The relatively low performance of individual A/S methods, the general difficulty of A/S warfare, and the vital need to ultimately defeat the U-boat (and not merely to protect shipping in the short-term), all impelled the Royal Navy to adopt a consistently holistic strategy which combined defensive and offensive tactics. An appreciation of A/S tactics and their technical limitations are recounted in the following Chapter. These details are crucial to understanding the problems of how the fast submarine was to be countered.

[99] 'Anti-Submarine Training,' ADM 205/3.

Chapter 2: Mastering the Submersible, 1939-1943

U-boats and their Tactics, 1939-43

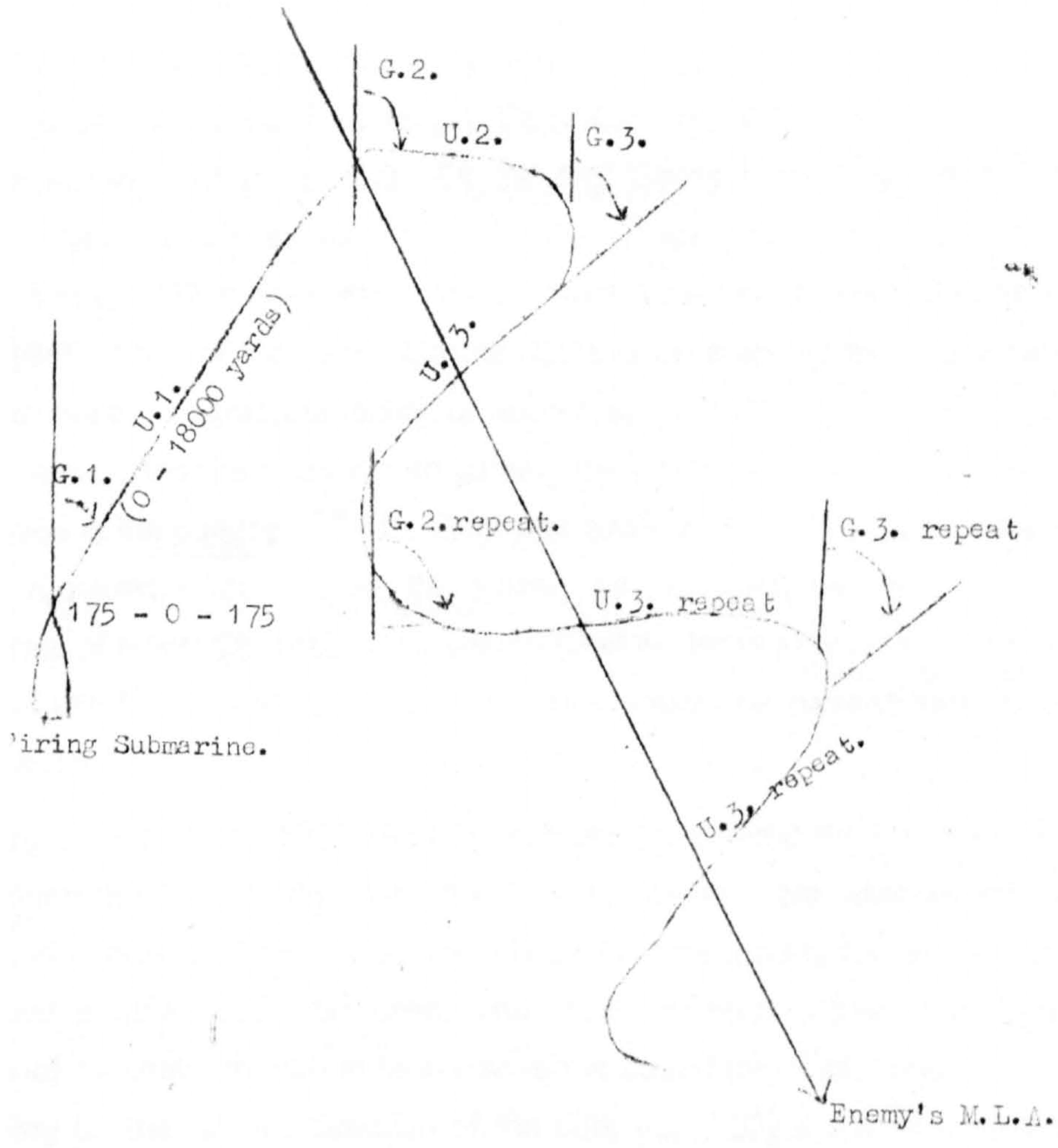
Anti-submarine tactics were designed to exploit the weaknesses in U-boat operations. For their part, U-boat commanders made every effort to capitalize on the submarine's chief characteristic and strength, which was its invisibility when submerged. They hoped to create surprise and attack from an ambush.[100] Such stealthy methods, however, were not conducive to finding targets, and this conundrum was to exercise the enemy throughout the war. For the attack itself, however, the U-boat gained great advantage by remaining undetected until the moment of striking. The U-boat was not only more likely to make an undisturbed, and therefore more accurate, attack but the target stood practically no chance of taking avoiding action. Amidst the mayhem created, it was then hoped that the U-boat could withdraw unmolested. The U-boat was forced to use such stratagems because advances in technology had made A/S forces deadly. There was, Admiral Max Horton, Flag Officer, Submarines, warned, '...no margin for mistakes in submarines, you are either alive or dead.'[101] The U-boat was not a vehicle well adapted to self-defence and the U-boat's use of stealth was a matter of necessity for self-preservation, which rather muddied the issue of the legality of unrestricted U-boat warfare.[102]

The defensive power of the U-boat was weak. They possessed little reserve of buoyancy (to allow rapid submergence) and were therefore sensitive to even minor damage during attacks by A/S forces. Initially, their defensive armament was puny, as befitted a vessel whose primary power was in her offensive weapons, principally salvoes of up to four torpedoes, which by the middle of the war included straight- or pattern-running torpedoes.[103] The pattern-runner, or LuT, torpedo carried out a ladder pattern which passed across the target's track, theoretically giving more opportunities for a hit {*Plate 7*}. The greatest chance of the torpedoes striking their target still

[100] High Command of the Navy, *The U-Boat Commander's Handbook, 1942, New Edition 1943*, (Gettysburg, PA: Thomas Publications, 1989), p. 17.
[101] W.S. Chalmers, *Max Horton and the Western Approaches* (London: Hodder and Stoughton, 1954), p. 106.
[102] Manson, *Diplomatic Ramifications*, pp. 5-6 and 113.
[103] 'Progress in Tactics, 1948,' DTSD, TSD.108/48, CB03016/48, 30 November 1948, ADM 239/144, p. 14.

Plate 7: Pattern-Running Torpedo

("Pattern-Running Torpedo Attack," from 'Future Anti-Submarine and Torpedo Policy and Equipment in Submarines (Short Title: F.A.T.S.),' Rear Admiral S. M. Raw, Flag Officer, Submarines, SM. 0149/224.0, 1 May 1951 (with amendment 3 March 1952), Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 143, RG 38, National Archives and Records Administration 2, College Park, Maryland, p. 33.)



occurred when firing ranges were short, ideally in the order of 300-800 yards, and fired from a position about 60° to 120° off the bow of the target. Long-range attacks posed severe fire control problems for the submarine – even when using LuT – and allowed the target time to take avoiding action.[104] Thus, the U-boat's ideal firing window was relatively small. This limitation was partially removed by the introduction of the German Naval Acoustic Torpedo (Gnat), which, it was assessed, could be fired from 5,000 yards and, being fitted with hydrophones which controlled the rudders, could home onto the target's propeller noise. The Gnat was effective against ships travelling between 12 and 19 knots, that is, travelling fast enough to produce sufficient HE on which the Gnat could home from a reasonable range, but slow enough for the 25 knot torpedo to be able to catch its target. Operationally, the weapon was not particularly effective in terms of ships sunk. Of the 640 Gnats fired, only 3% hit (though the Germans claimed 53% as successful).[105] The weapon was first used against convoys ONS18 and ON202 in September 1943, where Commander P.W. Burnett was Senior Officer (SO) of one of the Escort Groups. On this occasion, in the face of heavy U-boat attack, it was the aggressive tactics of Burnett and the other escort SOs, Horton noted, which '...prevented the enemy from gaining the initiative and resulted in comparatively light losses in the convoys.'[106] The Gnat was soon countered by tactical means and the use of a towed noise maker, the Foxer, as predicted by Leon Solomon in the Directorate of Naval Operational Research (DNOR) three months before the torpedoes were first used.[107] Nevertheless, escort tactics would now have to take account of this new weapon.

The design of the 1939-1943 U-boat was fundamentally the same as the boats used during the First World War, although their mechanical reliability and operational range had improved. To move at high speed the boat had to be on the surface, when the diesel engines could be used. The most common U-boat, the Type VII, was capable of 17 knots, though in heavy seas the speed might be reduced to 5-10 knots, depending on the relative direction of the sea, especially if the crew was to keep an efficient lookout. Once submerged, the British knew from trials with *U-570* captured in August 1941, that U-boats when propelled by electric motors had a maximum speed of

[104] Compton-Hall, 26 February 2000.
[105] G.J. Kirby, 'A History of the Torpedo: Part 3,' *Journal of the Royal Naval Scientific Service*, Vol. 27, No. 2 (1972), p. 85.
[106] 'Reports of Proceedings – Convoys ONS18 and ON202,' Admiral Max Horton, Commander-in-Chief, Western Approaches, 31 December 1943, Captain M.J. Evans, RN, Papers, IWM 65/25/1.
[107] 'Some Operational Implications of a Homing Torpedo,' L. Solomon, Report 36/43, 1 June 1943, ADM 219/52.

about 7½ knots, but this could only be maintained for about 2 hours before the battery was exhausted. The greatest submerged endurance and distance travelled could be achieved at about 2-2½ knots.[108] Ultimately, the U-boats underwater performance was limited because it could not re-charge its battery or re-cycle the breathing air while the boat was submerged (the latter probably being more of a limitation to the U-boat's underwater endurance of its than battery power). For submerged attacks, the U-boat's limited underwater mobility, constrained an approach to a narrow sector ahead of a convoy. However, a U-boat on the surface could use its high surface speed to attack over a much wider angle, theoretically extending all round a convoy, though use of very high speed gave escorts a better chance of sighting the incoming U-boat.

The easiest prey were independent ships or convoy stragglers: attacking convoys was an altogether more dangerous occupation, with the attendant risk of being overrun by the merchant ships, or attacked by the escort. As the proportion of ships in convoy increased, the Germans were faced with little option but to attack convoys. DASW noted in 1941 that the more daring U-boat Commanders were picking their targets and making individual attacks on each ship, though, the less courageous were content to fire spread salvoes from a distance. Although some U-boats had closed inside a convoy, this was normally when the columns were disordered, or where ships in the columns had fallen badly astern. Few U-boats were prepared to penetrate inside a closely formed convoy.[109] British intelligence, echoing German tactical instructions, assessed that U-boats would fire long-range salvoes whenever an opportunity arose, and were likely to attack the escort too.[110] The U-boat had to be submerged and reasonably stable to carry out the cumbersome procedure of manually reloading the torpedo tubes, which made multiple salvo attacks impossible. By the autumn of 1942 as a result of the '...recent rough handling...' by the escorts, the U-boats had adopted more diverse tactical stratagems. Night surface attacks were still preferred and attempts were made to lure escorts away from the convoy to give other U-boats a chance to attack, but submerged, daytime attacks were also being used more often (partly because, as less experienced U-boat captains took command they lacked the skill necessary for night surface attacks). This trend continued into 1943.[111] By March

[108] 'Information on U-Boats,' Part 13, 'Conduct of Anti-U-Boat Operations,' CB4097(13)(44), June 1944, NHB, Paragraphs 1472-1473 and Table I.
[109] 'U-boat Tactics,' in, 'Monthly Anti-Submarine Report, January 1941,' DASW, CB04050/41(1), [February 1941], NHB, p. 6.
[110] 'U-boat Methods of Combined Attack on Convoys, 1 February to 31 October 1941,' Naval Section [GC&CS, Bletchley Park], ZIP/ZG/116, 10 November 1941, ADM 223/1, pp. 15-16.
[111] 'Report on anti-convoy activity by Kptlt. Topp (U-boat tactics by a German Commander),' 1942, AIR 40/1821, pp. 3-4; Message DASW to various, 2024A/11 October, 11 October 1942,

of that year, the average torpedo firing range was about 3,000 yards, with about two-thirds of the attacks launched from about 2,000-4,000 yards.[112]

The extension of convoy had a dual effect on U-boat operations. Firstly, as *The U-Boat Commander's Handbook* noted:

> ...the concentration of numerous steamers to form convoys, the sea routes lose their characteristic peacetime appearance and become desolate, as it is only at relatively long intervals that a concentration of steamers passes along them.[113]

As British A/S operations improved and were reinforced by the release of A/S ships and Coastal Command aircraft from anti-invasion duties, so the U-boats were forced to operate further from the focal areas. In the open ocean, convoys could be dispersed to a greater extent, so the location of convoys became the most difficult challenge faced by the U-boats.[114] This was the second effect of convoy on U-boat operations: it induced them to disperse to locate their prey, and then to move at speed to concentrate for the attack. Crucially, this could only be achieved if they operated on the surface. The method adopted was an extension of the First War practice of several U-boats working together in what became the "combined attack" (better known as pack tactics). The primary purpose of the pack system was to maximise the number of contacts per U-boat by enabling all members of the pack to exploit a sighting made by any one of them. The U-boat in contact sent a high-frequency wireless telegraphy (H/F W/T) report in naval enigma to *Befehlshaber der Unterseeboote* (BdU, the U-boat High Command) ashore. The signal was then re-broadcast to the remainder of the patrol line. The ability of the shadower to operate unmolested while other members of the pack converged onto the convoy was vital to the success of the operation. Once a sufficient number of U-boats had concentrated around the convoy, BdU would order the attacks to begin. This control by W/T resulted in considerable radio traffic on H/F, as well as short range homing signals on M/F. There was no attempt at close tactical

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ADM 199/1732; 'Hints on Escort Work – Part III,' A/Captain J.D. Prentice, RCN, Captain (D) Halifax, Memorandum D.0-24-11, 21 May 1943, Folder CNA 7-6-5, Vol. 11023, RG 24, NAC.

112 Calculated from data in: Rohwer, *Critical Convoy Battles*, pp. 219-223. The average of the 30 firing ranges calculated by Rohwer is 3,269 yards (standard deviation, σ, 2,090 yards), or if the exceptionally long and short ranges are excluded, 2,978 yards (σ 1,194 yards). The average firing range estimated by the U-boats was 2,152 yards (σ 937 yards).

113 High Command of the Navy, *The U-Boat Commander's Handbook, 1942, New Edition 1943*, (Gettysburg, PA: Thomas Publications, 1989).

114 'Grand Admiral Dönitz on the U-boat War,' in, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB, p. 24.

co-ordination within the U-boat pack, but rather a crude attempt to overwhelm the escorts with a heavy concentration of U-boats.[115]

This system was well understood by the British, who also concluded that a pack of 25-30 U-boats might sink some 15-20 ships in a normal sized convoy of, say, 50 ships. But a pack would not function properly if too many U-boats tried to operate round a single convoy, so a typical pack consisted of 15-20 boats, which was in stark contrasts to the USN practice of using 3, or at most 4, submarines in co-ordinated attacks.[116] As Professor McCrea, DNOR, noted, because the U-boats had to be spread out in a search line to locate the convoy, it took some two to three days for the whole pack to concentrate round the convoy. The inevitable heavy use of W/T by the enemy provided cues for A/S forces. The delay before a strong attack could be mounted also allowed time for the threatened convoy escort usually to be reinforced with additional air cover and a support group of A/S vessels. Only about 70-80% of the pack normally made contact, mainly due to navigational difficulties, and many had difficulty remaining in touch with the convoy. About one in three U-boats that made contact were able to attack, and one in three of these attacks yielded a torpedo hit.[117] By contrast, the American submarines in the Pacific, albeit against a far less expert and determined defence, proved highly effective operating in small packs, with tactical control exercised by a senior officer at sea. Even with these limitations, the German U-boats operating in packs probably achieved three times the number of sinkings up to 1943 than would have been the case if the U-boats had operated individually.[118] The results would have been even greater had the U-boats had the benefit of wide-ranging air reconnaissance, leaving the U-boats to concentrate on sinking shipping. However, poor co-operation between the *Luftwaffe* and the U-boat arm, lack of sufficient numbers of long-range aircraft and ill-trained aircrews, scuppered any chance of the scheme working. In the main, U-boats had to provide their own reconnaissance, for which they were singularly ill-suited.[119]

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[115] 'U-boat Methods of Combined Attack on Convoys, 1 February to 31 October 1941,' Naval Section [GC&CS, Bletchley Park], ZIP/ZG/116, 10 November 1941, ADM 223/1, p. 5.
[116] M. Llewellyn-Jones, 'A Clash of Cultures: The Case for Large Convoys,' in, Peter Hore (ed.), *Patrick Blackett: Sailor, Scientist, Socialist* (London: Frank Cass, 2003), p. 142; 'Pack Tactics by Submarines of the United States Navy,' Section 5, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB.
[117] 'Effect of High Submerged Speed on U-boat Tactics,' W.H. McCrea, NORD, Report No. 20/45, 23 April 1945, ADM 219/225, p. 1.
[118] 'Pack Tactics by Submarines (Summary),' E.J. Williams, JTS-C No. 10, 21 February 1944, ADM 219/631, p. 1.
[119] 'Grand Admiral Dönitz on the U-boat War,' in, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB, p. 24.

Methods of Detecting and Attacking U-boats

On the Allied side, the level of operational co-operation between the air forces and navies was, by and large, excellent and provided one of the main sinews of the Allied success in defeating U-boats dependent on surface scouting and movement. Although the use of radar by aircraft is usually given the pride of place in their ability to detect surfaced U-boats, half of the contacts were made visually. However, binoculars were not routinely used until mid-1943, but thereafter some 20% of U-boat sightings involved their use (though on two-thirds of these occasions the binoculars were used for recognition purposes, rather than initial detection). The low usage was due partly to the focus in training on operation of new aircraft types and their increasingly complex equipment, and partly on the awkward observation positions in many of the aircraft. Although binoculars improved the visual detection range by almost 60%, they were heavy and tiring to use for more than 15 minutes at a time. Nevertheless:

> A good visual lookout is of outstanding importance in ...[anti-U-boat] operations. ...Although luck plays a big part in the sighting of U-boats, there is no doubt that the greatest number of sightings and attacks have gone to those crews with the best lookout. It is also a fact that large numbers of U-boats come within visual range of aircraft and pass unseen.[120]

At the same time, the Operational Research Section (ORS) at Coastal Command, recommended that

> Crews must not get into the habit of relying mainly on radar when the visibility conditions are such that visual lookouts are likely to pay bigger dividends. The <u>reverse</u> is true when visibility is poor.[121]

The value of radar for detection of surfaced U-boats at night or in low visibility had been recognised in early 1939, when experiments were started with radar equipped aircraft.[122] Radar also provided a valuable navigation aid, which for aircraft returning from long-range missions over the Atlantic could be a '...life saver.'[123] Improved detection meant that more U-boats were forced to dive (and even if not attacked) lost their surface mobility for hours at a time. Aircraft were especially valuable in this regard and the operational and psychological effects of constant air surveillance on submarines should not be lightly discounted.[124]

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[120] 'Coastal Command Manual of Anti-U-Boat Warfare,' May 1944, AIR 15/294, Article 1.
[121] 'Visual Sighting of U-Boats,' Wing Commander T.V. Stokes, RAAF, Overseas Headquarters, 12 December 1944, AWM 54, 81/4/81. [emphasis supplied]
[122] Minute, Wing Commander R.N. Waite, Wing Commander Plans, to SASO, 10 February 1939, AIR 15/38.
[123] 'Outline of Coastal Command's Anti-U-Boat Warfare 1939-August 1944,' Wing Commander T.V. Stokes, [20 September 1944], AWM 54, 81/4/81.
[124] R. Compton-Hall to A. Hampshire, [c. 1998].

Perhaps the greatest problem for the aircraft of Coastal Command was that

> ..."half of the long-range sorties failed to find their designated convoy because of bad homing, while inter-communication left much to be desired." In late 1942 the RAF set up a special training groups with Western Approaches, and in 1943 "remarkable improvements" were registered, with a 90% contact rate being achieved.[125]

These direct convoy escort operations were supported by aircraft missions over the main transit routes. Thus intensive patrols were flown over the Bay of Biscay, together with searches over ocean transit routes based, whenever possible, on intelligence cuing.[126] Professor Williams in DNOR, supported by Professor Blackett, noted that Coastal Command patrols over the Bay were relatively profitable for purely offensive operations in 1942-43 and had "...worked out in great detail the best methods of conducting such an offensive by a balanced force of day and night aircraft...."[127] The Bay, Williams reasoned, presented a small area to search, compared to the total area of U-boat operations in the Atlantic. (Williams does not mention that in the area around threatened convoys there would also be a relatively high density of U-boats.) This made up for the relatively short time the U-boats spent transiting the Bay, compared to the time they spent on operations. The Bay was therefore an area of comparatively high U-boat density, as well as being accessible by large numbers of medium range A/S aircraft.[128] Furthermore, the U-boats could not disengage, for they had to cross the Bay if they were to get to their ocean operational areas. These operations, and those around convoys, provided aircraft with the opportunity to attack U-boats. Now that they were equipped with effective aerial depth-charges, through the work of ORS and Coastal Command's Development Unit, aircraft became effective U-boat killers. This was starkly illustrated by the proportion of lethal attacks against surfaced U-boats rising from 8% to 28% during 1943, with aircraft attacks accounting for some 70% of U-boat casualties during the last half of the year.[129] Unfortunately, this lethal capability was not to continue, as will be seen.

The Royal Navy (and its allies) provided surface vessels for the direct protection of convoys and, at times, for independent offensive operations. About half the U-boats

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[125] H.P. Willmott, 'The Organisations: The Admiralty and the Western Approaches,' in, Stephen Howarth and Derek Law (eds.), *The Battle of the Atlantic 1939-1945: The 50th Anniversary International Naval Conference* (London: Greenhill Books, 1994), p. 184.
[126] 'Coastal Command Manual of Anti-U-Boat Warfare,' May 1944, AIR 15/294, Article 21.
[127] Bernard Lovell, *P.M.S. Blackett: A biographical memoir* (London: The Royal Society, 1976), p. 64; 'Note on Relation Between the Use of Aircraft to Give Cover to Convoys and in the Bay,' P.M.S. Blackett, CAOR, 22 March 1943, ADM 205/30.
[128] 'A/S Operations against Snort U-boats Working Inshore,' E.J. Williams, DNOR, Report No. 66/44, 29 August 1944, ADM 219/148.
[129] See Appendix 4.

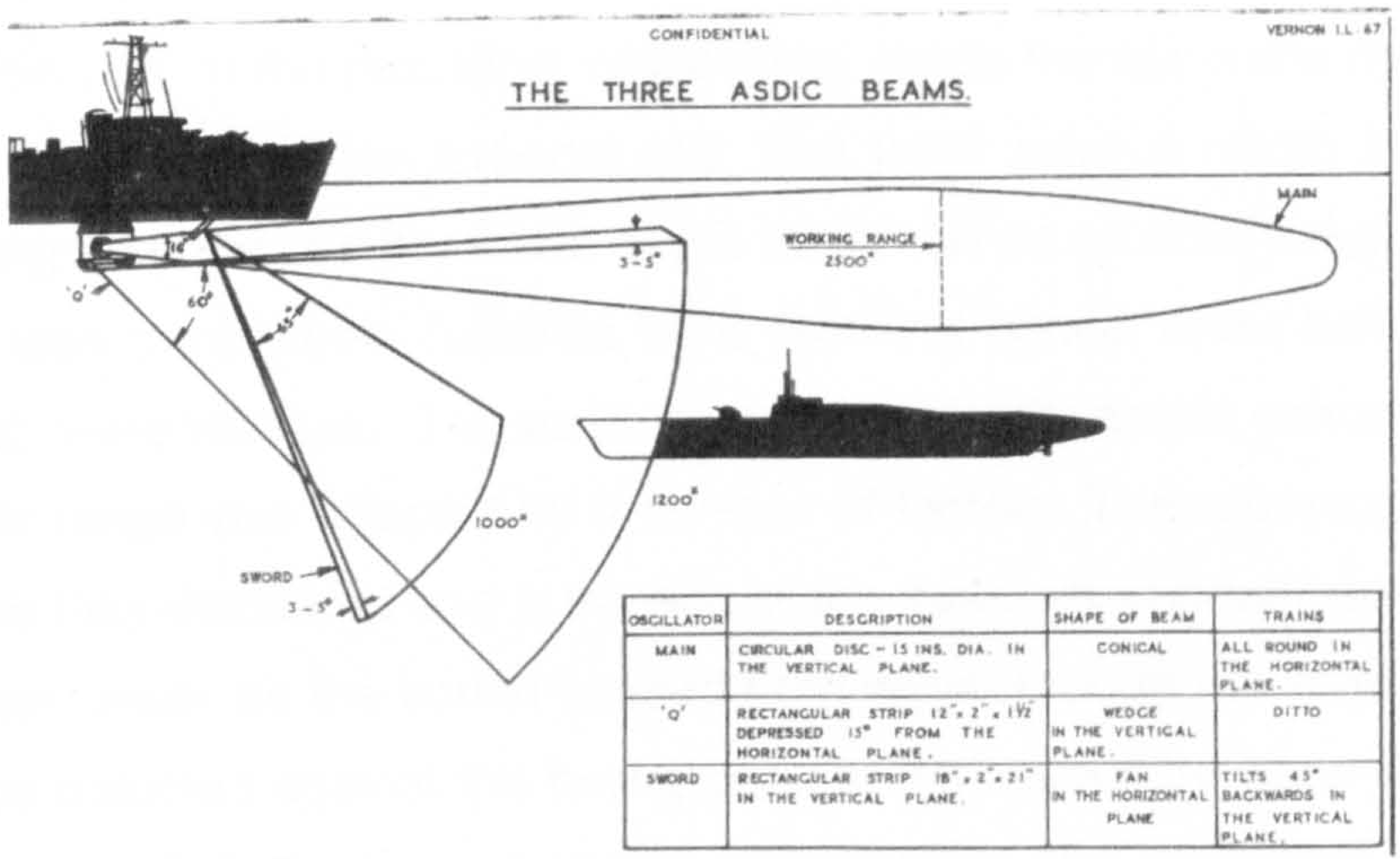
found by A/S ships were initially on the surface. Just over 40% of these U-boats were detected visually and the remainder by radar, which, as with aircraft, was of greatest value at night or in poor visibility.[130] However, the earlier, lower frequency, longer wave-length, radars suffered from considerable "clutter", caused by unwanted echoes from waves, which in rough seas might extend as far as 2,000-3,000 yards from the ship and seriously reduced the chance of detecting a U-boat. Even in calm seas, these sets could not hold contacts inside about 1,000 yards. Closing to visual range was therefore difficult, while at longer ranges the problem was in identifying a contact by radar alone. At 4,000 yards, for example, a surfaced U-boat gave an echo practically indistinguishable from a destroyer. The means of tentatively identifying a contact was by the range of first detection, and if it first appeared in a position not previously occupied by an echo. The eventually introduction of the Plan Position Indicator (PPI) radar display was invaluable because it gave a continuous view of contacts all-round the ship. Even with these limitations, radar allowed escorts to maintain almost unbroken coverage of the perimeter against approaching U-boats. It also relieved them of the constant worry over station keeping on the convoy, for colliding with merchant ships in poor visibility was a constant worry for escorts without radar. It also allowed them to co-ordinate their movements during U-boat hunts. Distant escorts could maintain touch with the convoy, even in poor weather, and they were themselves less likely to be confused with enemy contacts.[131]

If the U-boat was submerged, the escorts used the asdic to gain detection and almost half of the initial detections of U-boats were by this means.[132] By mid-1942 a new asdic, the Type 144, had been introduced into the Fleet which used the same oscillator as the earlier sets, but the inboard equipment had been completely redesigned to squeeze the last ounce of information out of the underwater sound.[133] Much of this development was carried out under the supervision of J. Anderson, the Superintendent Scientist at HM Anti-Submarine Experimental Establishment, Fairlie

[130] 'Progress in Underwater Warfare, 1949,' DTASW, TASW.30/50, CB04050(49), 17 July 1950, ADM 239/274, p. 79.
[131] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Article 93.
[132] 'Progress in Underwater Warfare, 1949,' DTASW, TASW.30/50, CB04050(49), 17 July 1950, ADM 239/274, p. 79.
[133] 'The Asdic and its Associated Weapons,' W.E. Dawson, ER30, HM Underwater Detection Establishment, Portland, February 1947, DERA, AN.15971, p. 4.

Plate 8: Asdic Beams

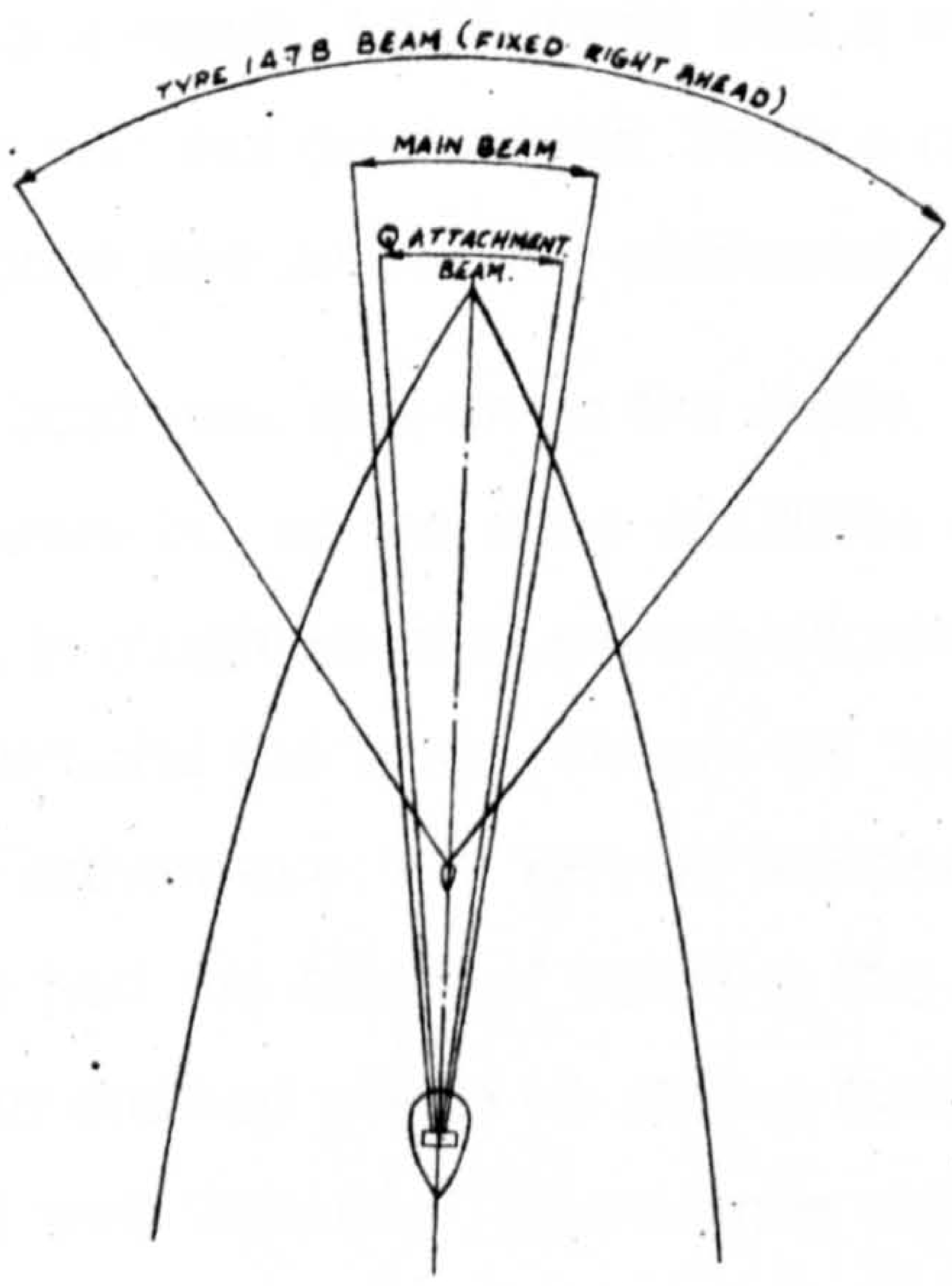
(Adams Papers)



OSCILLATOR	DESCRIPTION	SHAPE OF BEAM	TRAINS
MAIN	CIRCULAR DISC - 15 INS. DIA. IN THE VERTICAL PLANE.	CONICAL	ALL ROUND IN THE HORIZONTAL PLANE.
'Q'	RECTANGULAR STRIP 12" x 2" x 1½" DEPRESSED 15° FROM THE HORIZONTAL PLANE.	WEDGE IN THE VERTICAL PLANE.	DITTO
SWORD	RECTANGULAR STRIP 18" x 2" x 21" IN THE VERTICAL PLANE.	FAN IN THE HORIZONTAL PLANE	TILTS 45° BACKWARDS IN THE VERTICAL PLANE.

Three Asdic Beams

FIG. 2.



Three Asdic Beams (Plan View)

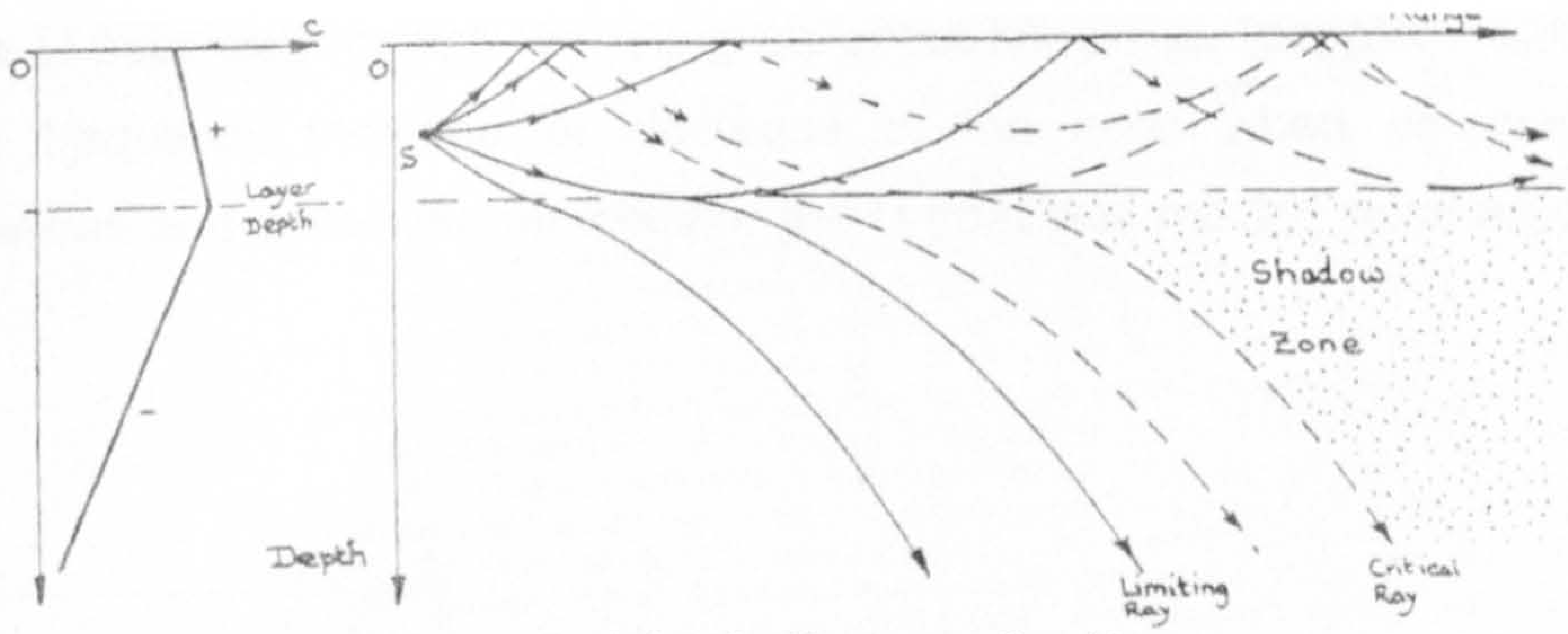


Fig. 3.11 Positive Gradient over Negative

Effects of Temperature Gradients on Asdic Beams

(HMA/SEE), who had been involved in asdic development from its earliest days.[134] The Type 144 transmitted and received sound over a narrow 16º conical, "searchlight" beam which could be rotated in the horizontal plane through 360º but could not be depressed {*Plate 8*}. In the receiving, or listening, mode the set could detect returning echoes as well as U-boat (or torpedo) HE. The latter gave a rough bearing but, of course, no range, so the primary mode of the asdic was as an echo-ranging set when a sound pulse was transmitted, followed by a listening period when echoes, hopefully from a U-boat, were received. The asdic could theoretically detect echoes out to 2,500 yards, but this range was affected by a number of factors. The returning echoes were weak because they contained only a fraction of the transmitted power due to spreading and absorption losses as the sound passed both ways through the water. The echoes also had to be detected against the background noise caused by water flowing around the asdic dome, HE from the escort's own propellers, and unwanted asdic echoes, known as "reverberations", produced by discontinuities in the water structure, the surface and the seabed. As a result, 1,500 yards was a more realistic working range, though even then detection was not guaranteed. Such a range was wholly inadequate to provide complete asdic coverage around the perimeter of a convoy {*Plate 9*}.

For example, if a U-boat was end-on to the asdic, its reflecting area would be considerably less than if beam-on, so the echo would be weaker, or possibly masked by the U-boat's wake. And, in rough weather severe pitching by the escort would cause highly aerated water to surround the asdic, known as "quenching", which interrupted the reception of echoes. Furthermore, the vertical temperature structure of the water was not constant, and this had the effect of bending the asdic beam. When this was severe, shadow zones were created where no pulses from the asdic penetrated. If the U-boat was in this zone, it was "invisible". Sometimes definite submarine-like echoes, termed "non-subs", were obtained from wrecks, rocks or shoals of fish. Thus classification of echoes was important and could be assisted by HE from the target, or, when the U-boat was moving, by using an effect known as "doppler", which was an apparent frequency increase or decrease in the echo when compared to the reverberations and depended on whether the U-boat was moving relatively towards or

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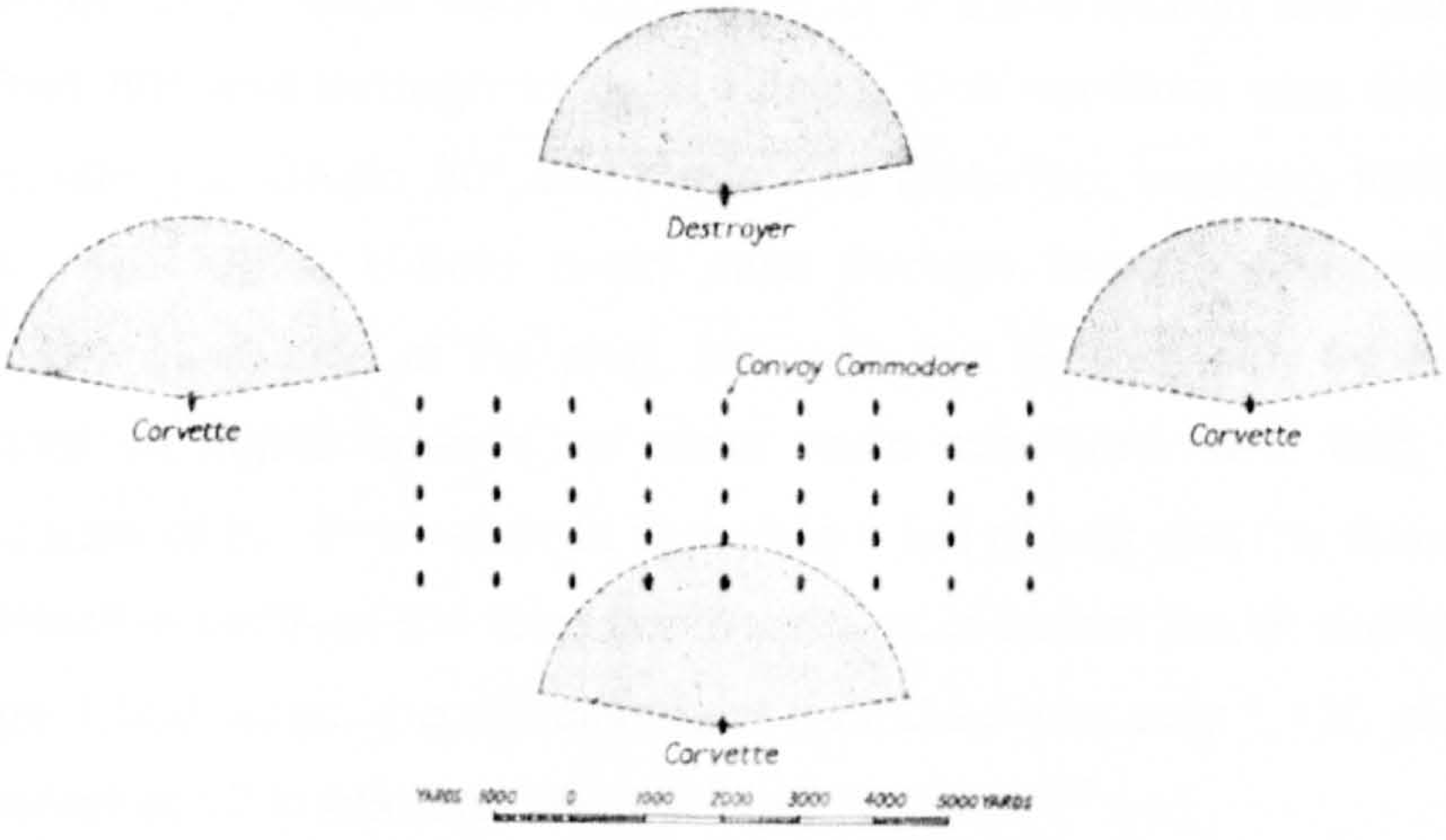
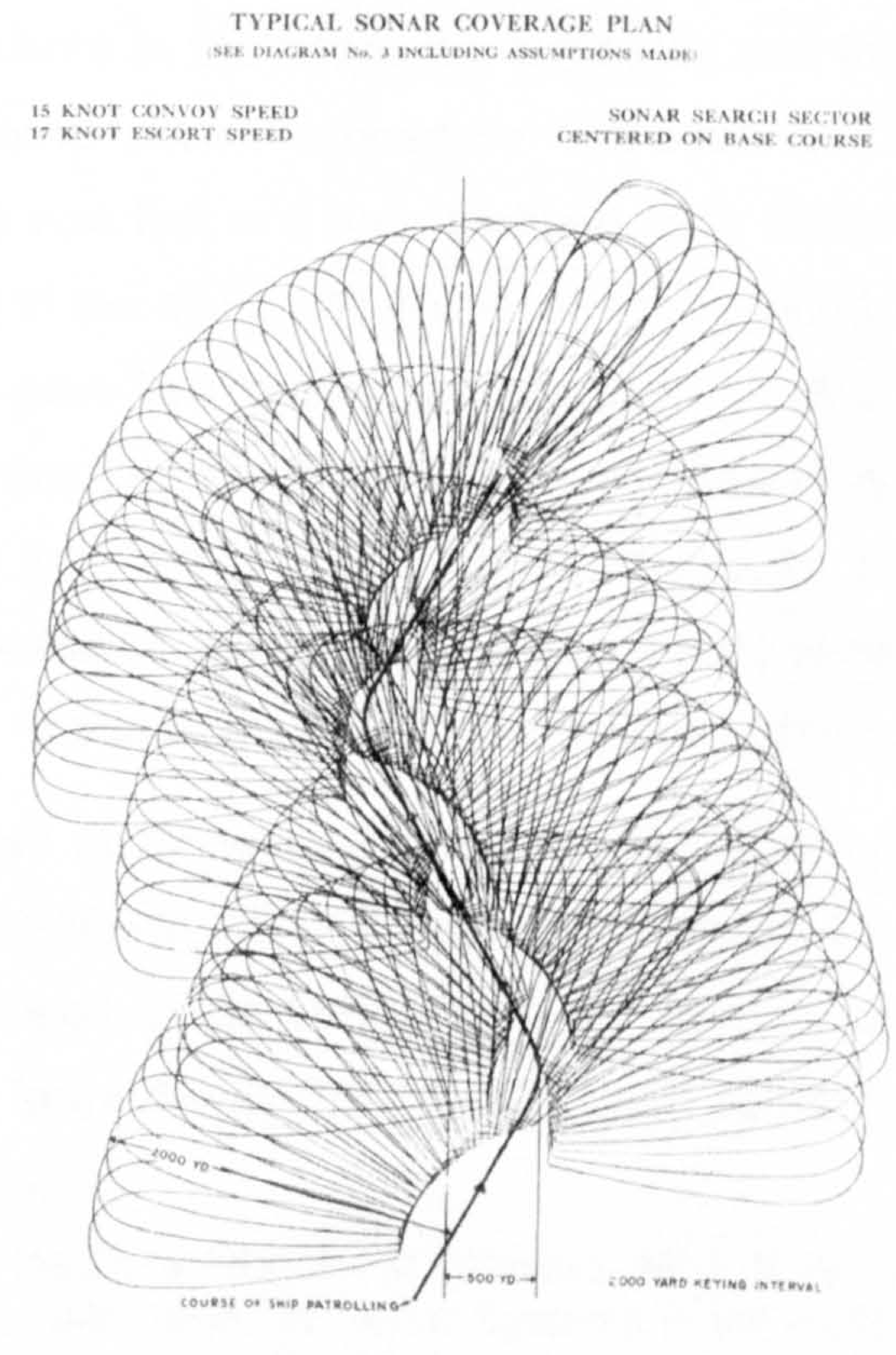
[134] A.B. Wood, OBE, DSc, 'From Board of Invention and Research to Royal Naval Scientific Service,' in, *Journal of the Naval Scientific Service*, Vol. 20, No. 4 (July 1965), pp. 16-97, CCAC, GOEV 3/7; 'Anti-Submarine Measures in World War I,' Commander F. Barely, Historical Section, S.5659, Searches Vol. 29, 30 November 1960, NHB.

Plate 9: Asdic Coverage and Asdic Sweep

"Asdic Coverage for a 45-ship Convoy," from Stephen Roskill, *The War at Sea 1939-1945*, Vol. I: *The Defensive* (London: HMSO, 1954), p. 465; Typical Sonar Coverage Plan,' from 'U.S. Fleet, Anti-Submarine and Escort of Convoy Instructions (BUSCIs),' FTP 223A, January 1945, File 79/532, Directorate of History and Heritage, Department of National Defence, Ottawa, Canada, p. 4-14.



Asdic Coverage in Relation to a Convoy



Asdic Sweep Coverage as Ship Advances

away from the escort.[135] Perhaps the most important factor in gaining detection was whether the operators were alert, and this could be heightened by their knowledge that a U-boat was in the vicinity.

Escorts would normally search using the asdic to sweep over the forward arc from 80° off the port bow to 80° off the starboard bow. (i.e. Red 80° to Green 80°). The arc was covered in 5° steps each consisting of a transmission and listening cycle, starting at Red 80° and through to dead ahead. The oscillator was then rotated aft without transmitting to Green 80° and the sweep restarted, stepping forward again to dead ahead (*Plate 9*}. A U-boat could pass through the arc while the asdic was searching on the other side of the ship, although this was unlikely for escort speeds below 14 knots. At higher speeds, or when asdic conditions were bad, the arc was reduced. Because of the time taken to complete a full sweep and the movement of the escort, the effective width of the lane searched was reduced. So, in round terms, for a working range 1,500 yards, the effective lane searched was only 1,100 yards on either side for an escort at 12 knots, and 950 yards at 18 knots.[136]

Once a contact was gained, its distance from the escort was available from the asdic range recorder but there was no means of directly measuring the bearing of the U-boat. Determining where in the beam the target lay and thus calculating its bearing relied on the cumbersome “cut-on” procedure. The asdic was trained off to one side of the target until contact was lost and then stepped back in 2½° steps until contact was regained. The bearing of the asdic was noted, and the procedure repeated on the other side of the echo. This gave two “cut-on” bearings, and midway between them was the supposed target's centre bearing but there were inherent errors due to the target's movement during the time the procedure took. Moreover, neither of these bearings were accurate because the boundaries of the target echo were not sharply defined. For practical purposes the “cut-ons” could be measured to within ±5°.[137]

In the early stages of the war attacks were made with depth-charges, filled with either 290-lb. Amatol or 300-lb. Minol fillings and released from the escort's stern and dropped far enough ahead of the U-boat to allow them to sink to the U-boat's depth before they exploded. Immediately the escort gained contact, she turned to place the

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[135] ‘The Asdic Beam,’ in ‘Asdic Notebook,’ M. Walford, MLJ; H.W. Smith, ‘Countering the Fast Conventional Submarine, 1946-1956,’ in ‘Sonar Systems in the RCN, 1945-68,’ Partial Draft, 15 January 1997, DHH; Commodore (D) Western Approaches to DAUD, 16 July 1944, ADM 217/90; ‘Monthly Anti-Submarine Report, October 1944,’ ADM 199/2061, p. 3.
[136] ‘A/S Screening,’ Part 3, ‘Conduct of Anti-U-Boat Operations,’ CB4097(3)(44), June 1944, NHB, Tables I and II.
[137] ‘Type 144. Trials of Operating Procedure,’ HMA/SEE, Fairlie, Internal Report No. 159, December 1943, ADM 259/382, p. 7.

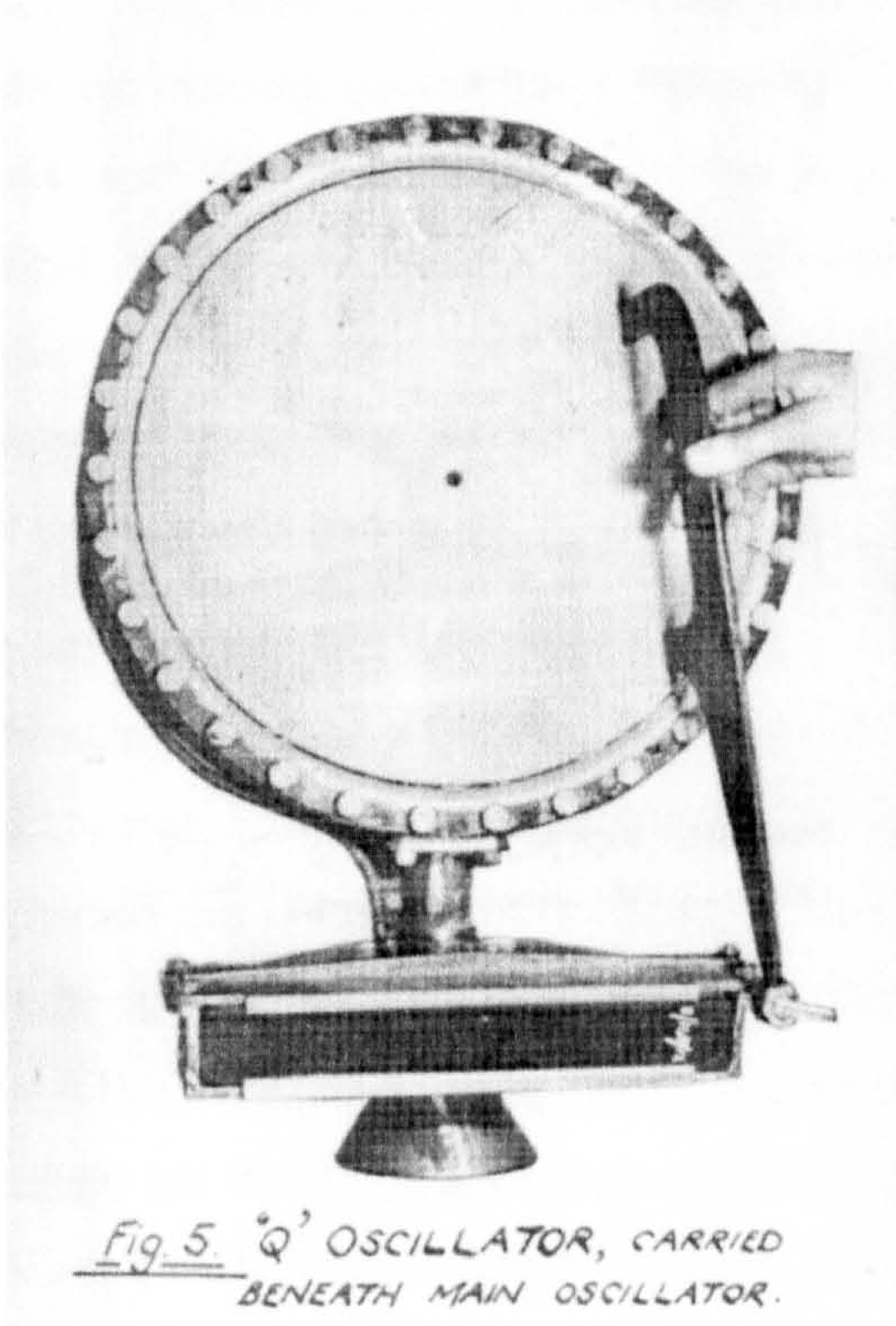
asdic echo directly on the ship's head, otherwise it was not possible to resolve how much of the observed bearing movement was due to the ship's or the U-boat's crossing components. Thus, with knowledge of whether the U-boat was moving left or right and with an estimate of her movement towards or away, from the echo's doppler, a rough course of the U-boat was obtained. Ideally an attack was started from a range of 1,000-1,500 yards and at a speed of 12-15 knots. The asdic system could only calculate a collision course that would take the escort directly over the U-boat. So a throw-off, inspired by guesswork and honed by practice, had to be applied to the attack course to take the escort's stern over the aim point ahead of the U-boat. This throw-off might be as much as 45º against a deep U-boat travelling at 6 knots.[138]

Trials had demonstrated that the asdic was able to locate a U-boat with an average radial error of some 20 yards in the horizontal plane, but, at first there was no means of directly measuring the U-boat's depth. Because the asdic could not be depressed, a shallow U-boat would pass out of the asdic beam at close range, while a deep U-boat would be lost sooner. This effect could be used to provide a rough estimation of the depth, so, if contact were lost at 100 yards the target could be between 50 and 100 feet, whereas if contact were lost at 400 yards the target depth was could be between 200 and 400 feet.[139] However, if contact was lost the estimation of the U-boat's position also degraded to a radial error of some 100 yards. This was well outside the 7-8 yards lethal range of a single depth-charge. At 13-17 yards they could cause enough damage to force the U-boat to surface, while at 27-33 yards range a depth-charge would severely shake the U-boat and was sufficient to cause the U-boat to break off a torpedo attack.[140] To mitigate the aiming errors, the standard attack was made with 10 depth-charges, in two 5-charge patterns roughly coincident in plan and, depending on the assessed depth of the U-boat, separated by 90-350 feet in depth. It is no wonder that the probability of a kill with depth-charges was about 6% per attack on a U-boat at medium depth.[141] If the U-boat were to evade by going very deep, in the order of 500-700 feet, the normal depth-charge attack stood little chance of success. For this circumstance the "Creeping Attack" was promulgated in the autumn

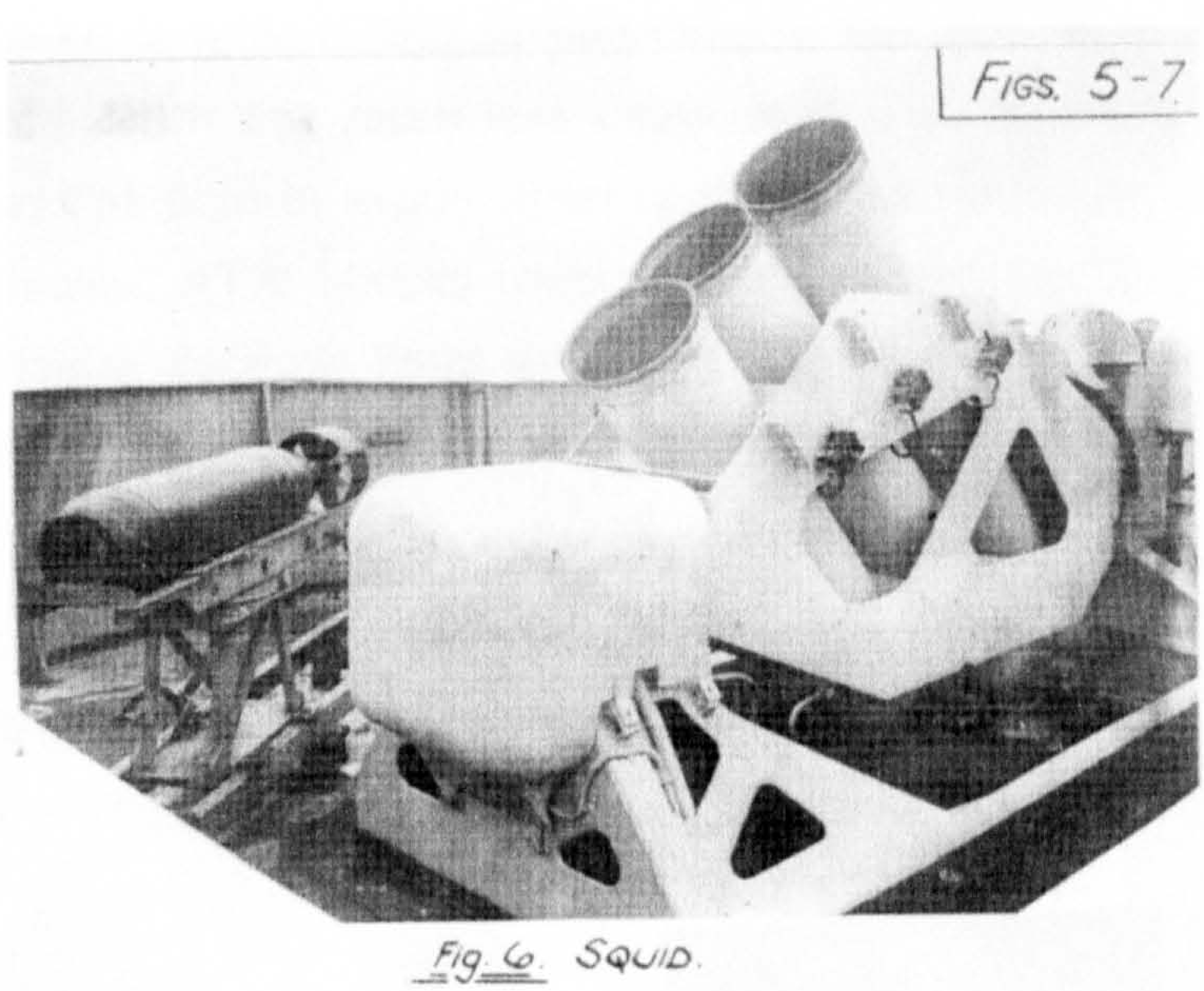
[138] 'Asdic Operating and Control: Supplementary Notes on Procedure and Control,' CB4127(4)(45), ASW 304/45, July 1945, NHB, p. 9.
[139] 'Detection, Attacking, Hunting,' CB4097(2)(41), December 1941, Box 468, RG 38, NARA2, paragraph 77.
[140] The variation of ranges given reflect the alternate explosive fillings of the depth-charges. The Mark X depth-charge, fired singly from the torpedo tubes of a few escorts, contained a ton of explosive, but no successes were recorded with this weapon.
[141] 'Conduct of Anti-U-Boat Operations – Part 10 – A/S Weapons,' DASW, CB4097(10)(44), July 1944, Box 468, RG 38, NARA2, paragraphs 1093 and 1044.

Plate 10: Type 144 Asdic Oscillator (with "Q" Attachment) and Squid

('Asdic & Its Associated Weapons', HM Underwater Detection Establishment, Portland, ACSIL/ADM/47/273, February 1947, Records of the Office of the Chief of Naval Operations: Registered Publications Section, U.S. Navy Technical Publications, 1901-1960, Box 161, RG 38, National Archives and Records Administration 2, College Park, Washington, D.C.)



Type 144 Asdic Oscillator with "Q" Attachment



Single Squid Mounting, showing projectile of 1943, which was controlled by an escort which remained in asdic contact and who controlled up to three other ships to fire a barrage of 62 depth-charges at the U-boat. The attack took about 3 minutes to complete, but had a 75% kill rate provided the enemy remained quiescent until the moment of attack.[142] Holding contact at close range was largely solved by the "Q" Attachment, an additional asdic with a narrow horizontal but 60° vertical beam, slaved to the main set {*Plate 10*}. But accurate depth measurement had to wait the introduction of the short-range Type 147B asdic, fitted in addition to the Type 144 and "Q". It was fixed on the ship's head, and had a 60° horizontal and 2½° vertical beam, which could be depressed to a maximum angle of 45°. By noting the angle of depression and the target's range its depth could be calculated.[143] The main error, however, in the attack remained that caused by the inexact measurement of the target's bearing.

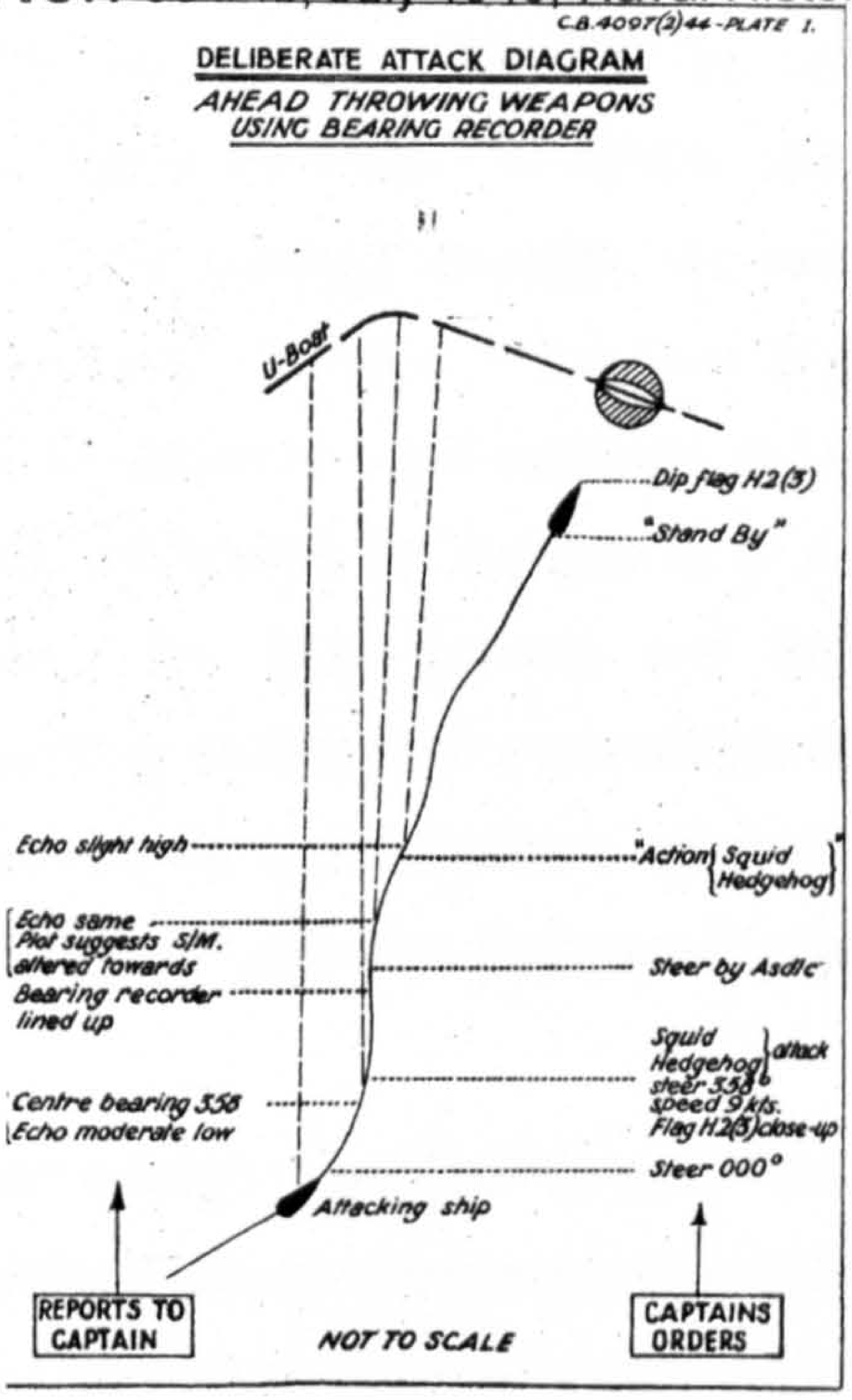
Most of the limitations of depth-charge attacks were eliminated by the introduction of ahead throwing weapons (ATWs) fired when the escort was still some 200-300 yards from the U-boat. Contact could normally be held on the main asdic at the moment of firing, provided the U-boat was no deeper than about 260 feet, or on "Q" down to over 1500 feet depth (which was well over the crush depth of any U-boat). There were two types of ATW. The Hedgehog fired 24 contact-fused bombs into a 40 yard diameter circle centred on the U-boats future position, and the ultimate wartime weapon system, the Squid, which fired 3 depth-charge like bombs to form a 40 yard sided triangle, timed to explode at the U-boat's depth {*Plate 10*}. A double-Squid fired two of these patterns, arranged to explode 60 feet apart in depth. The ATW projectiles were also designed to have a high sinking rate, so the time taken for the bombs to reach the target's depth was much less than during a depth-charge attack and this gave the U-boat less time to evade when compared to Hedgehog or depth-charges {*Plate 11*}. Moreover, ATW attacks were normally carried out at slower, deliberate speed of 7-12 knots, because there was practically no danger of the attacking ship being damaged by the exploding pattern, so the U-boat had no cue as to when the attack was launched.

When attacking with ATW, the escort steered for the centre bearing of the asdic contact with alterations made to keep the contact dead ahead. The deflection was then obtained from the bearing recorder or by estimation, which gave the angle the weapon

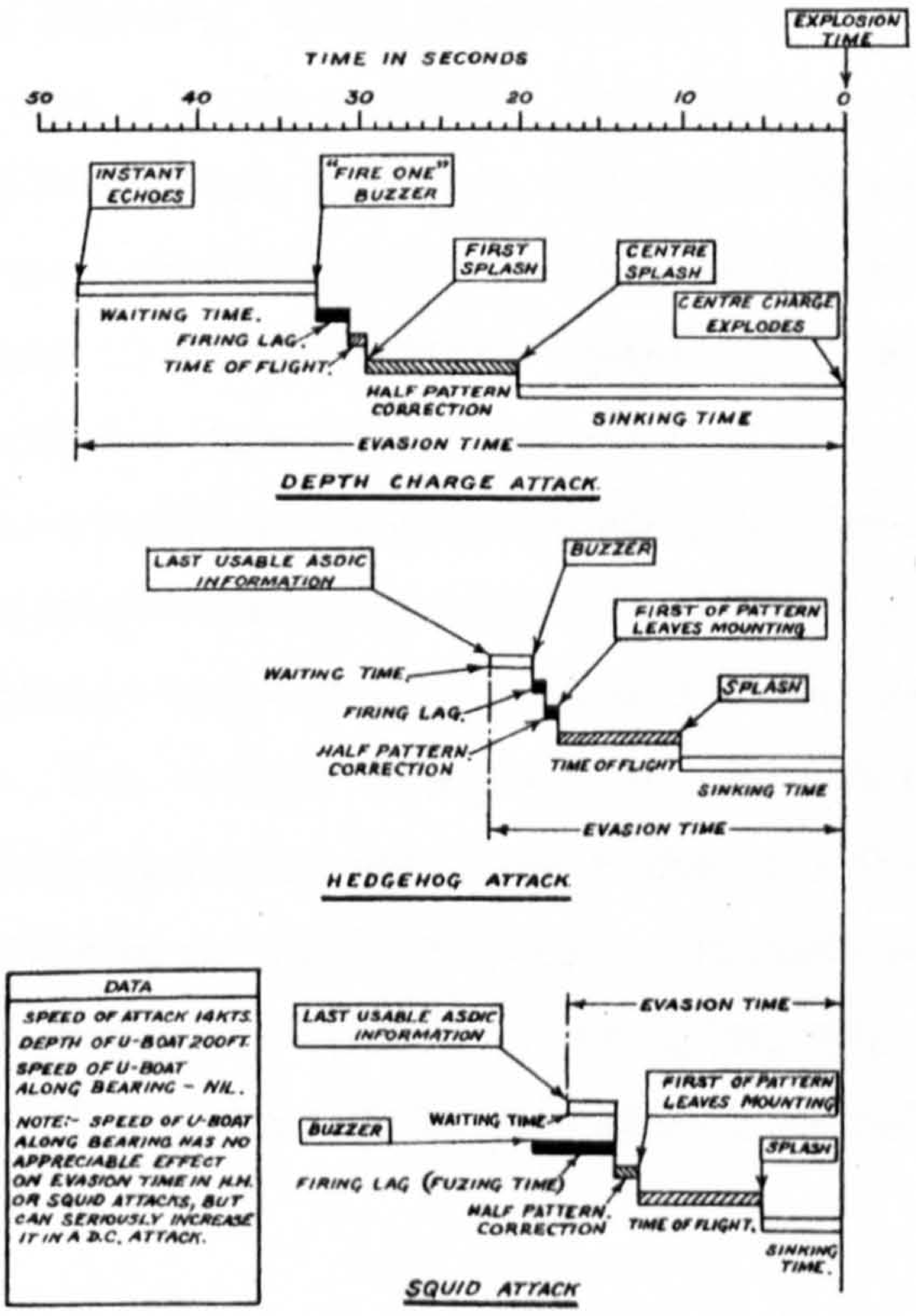
[142] 'Creeping Attack,' Admiralty Message, DTG 181904A August 1943, NAA(M): MP1185/8, 1932/3/45.
[143] 'Asdic Notebook,' MLJ, p. 54.

Plate 11: ATW Attack Method and Comparison of Evasion Time in A/S Weapon Attacks

'Asdic Operating and Control: Supplementary Notes on Procedure and Control,' C.B.4127(4)(45), A/SW 304/45, July 1945, Naval Historical Branch, p. 24.



ATW Attack Method



Comparison of Evasion Time in A/S Weapon Attacks had to be aimed off the centre bearing of the asdic contact in order to allow for the time of flight and sinking time of the projectiles. This was known as the "Gun Bearing" and as soon as reasonably consistent readings were established during the run-in, the escort altered course to this bearing. In ships with the latest gear, this was done by ordering the helmsman to "steer by asdic" in which case he followed an indicator controlled by the settings on the bearing recorder. As the range closed, the escort's heading was altered to follow any changes in the Gun Bearing. It took some time for the Bearing Recorder to settle down on new settings, so, especially during the last 30 seconds before firing it was preferable for the escort to remain on the same course. Small discrepancies between the Gun Bearing and the ship's heading could be eliminated by the ATW mounting, however, the prediction of the target's future position was nowhere as sophisticated as contemporary gunnery systems and against an evading U-boat it was advisable to delay the moment of attack until the enemy became quiescent.

Exercises showed that against a shallow U-boat, Hedgehog gave a 60% chance of success, while a 10-charge depth-charge pattern achieved 20%.[144] Operational results, however, gave a more stark comparison. Although Hedgehog initially achieved only a 7½% kill rate, this eventually improved to 28½%, while depth-charge attacks started at 3% and only improved to 6% (largely due to improved explosive content of the charges). Squid was a more complex, integrated system whose operational performance increased from 21½% to 60% by the end of the war. Put another way, the quantity of explosives required by each of these weapons to sink a U-boat was: depth-charges, 23 tons (for the 10-charge pattern); Hedgehog, 2 tons; and Squid 0.7 tons. These heavy bombardments proved the resilience of U-boats to withstand attack. Squid was the preferred weapon during A/S engagements, for not only was it the most lethal weapon, but like depth-charges and unlike the contact-fused Hedgehog, near misses had a morale effect and the chance of causing cumulative damage to a U-boat, which could force it to the surface where it could be despatched by ramming or gunfire.[145] Because the target was not overrun during ATW attacks, it was often possible for the attacking ship to remain in contact, and therefore mount another attack at short notice. ATWs were thus semi-automated, precision weapons that largely eliminated human error. Especially with Squid, attacks against slow wartime U-boats

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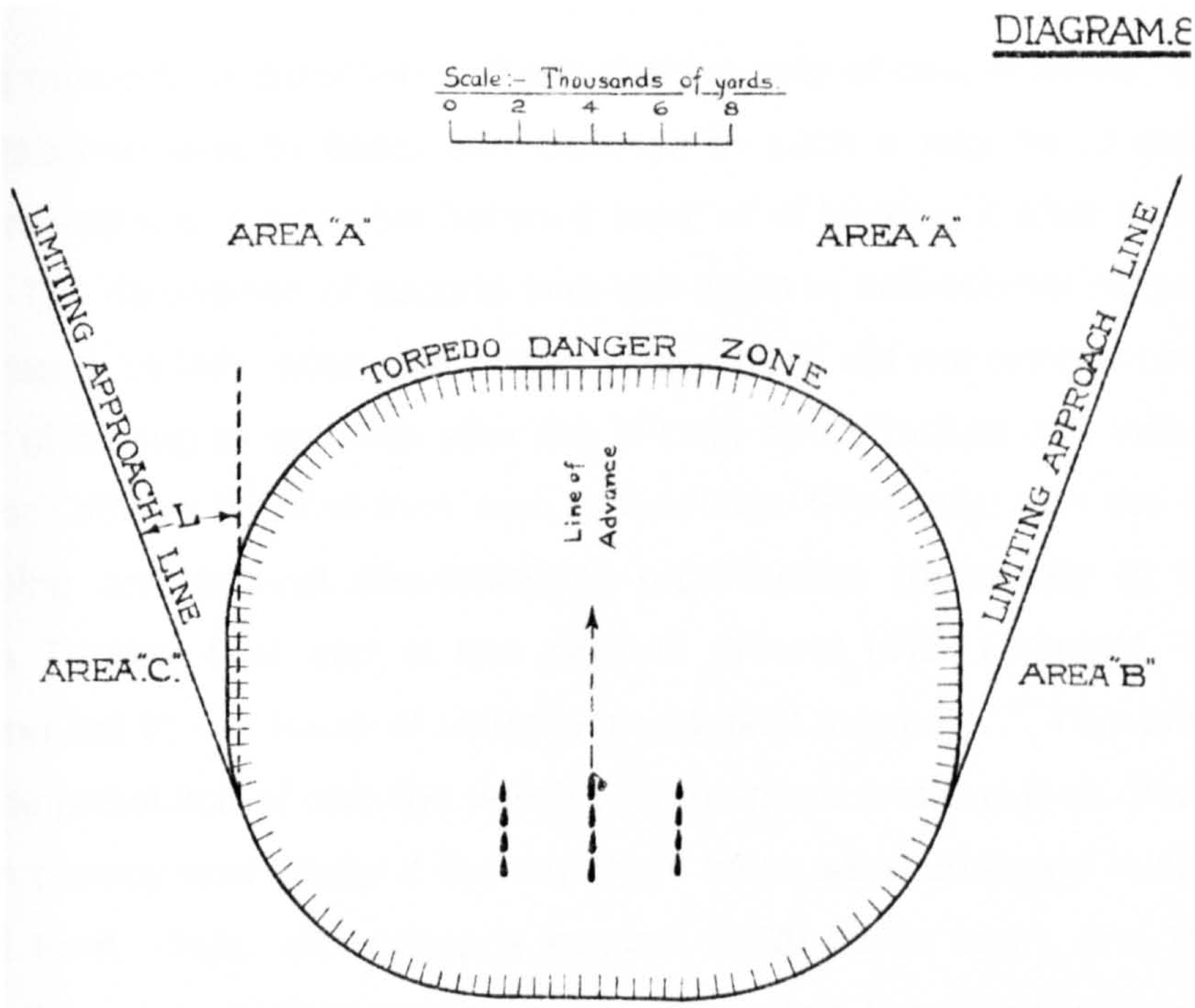
[144] 'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2, paragraphs 195 and 200.
[145] 'The Asdic and its Associated Weapons,' DERA, AN.15971, p. 11.

Plate 12: Limiting Lines of Submerged Approach

'Manual of Anti-Submarine Warfare, 1939,' Tactical Division, CB 3044, February 1939, Naval Historical Branch.



Note:- The outward slope of the limiting approach lines is such that :-

$$\text{Sin. angle L} = \frac{\text{Speed of Submarine}}{\text{Speed of Fleet}}$$

(This diagram show the calculation for a fleet. For a slower convoy, the TDZ would be wider and the LLSuA would be at greater angles.)

were comparatively academic affairs. They required a different philosophical approach from the A/S teams by emphasizing attention to detail and accuracy and deliberate stalking of the U-boat up to the moment of firing. Gone was the "artistry" of the depth-charge attack, as A/S warfare became more remote and mechanical.

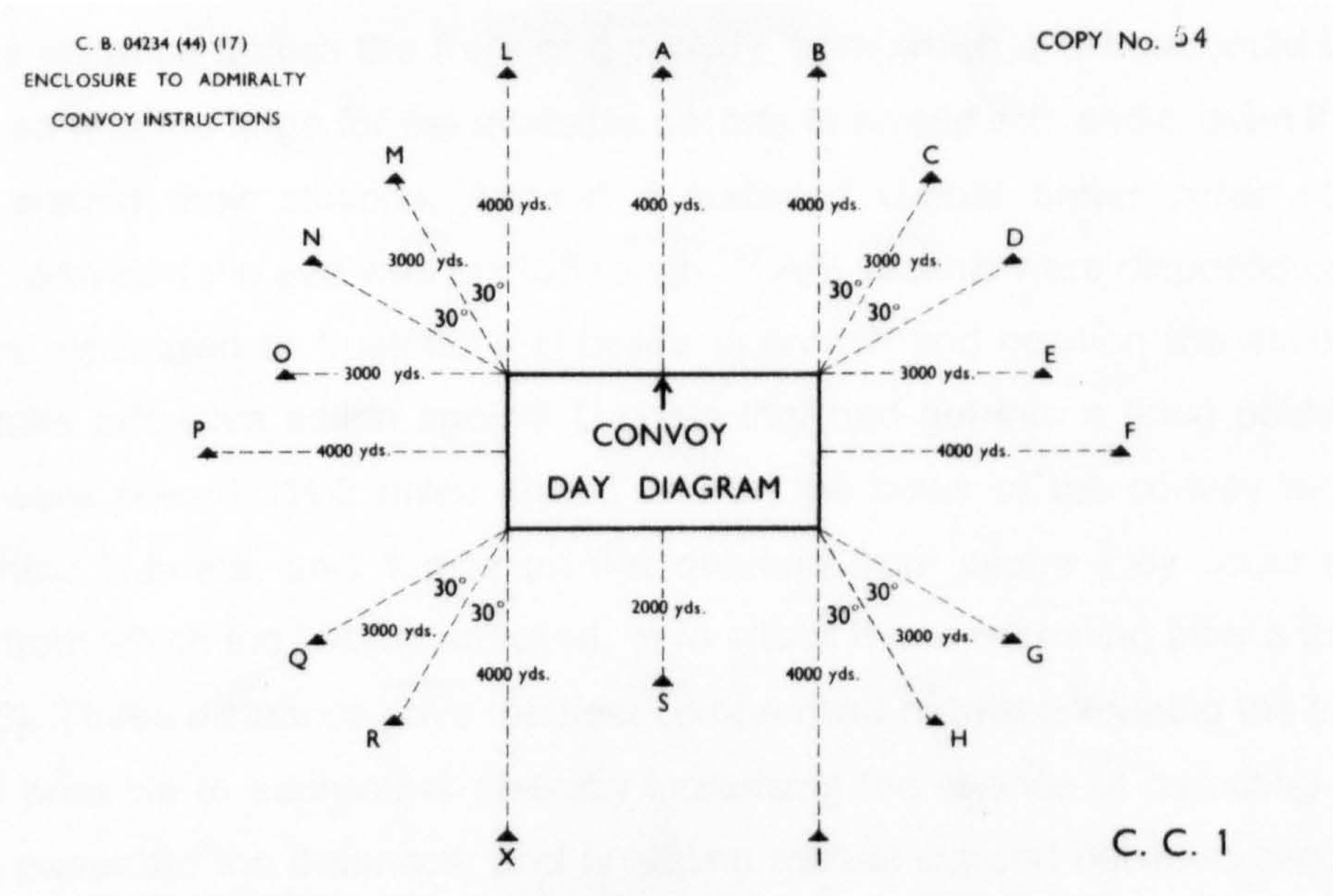
Anti-Submarine Screening and Escort Diagrams

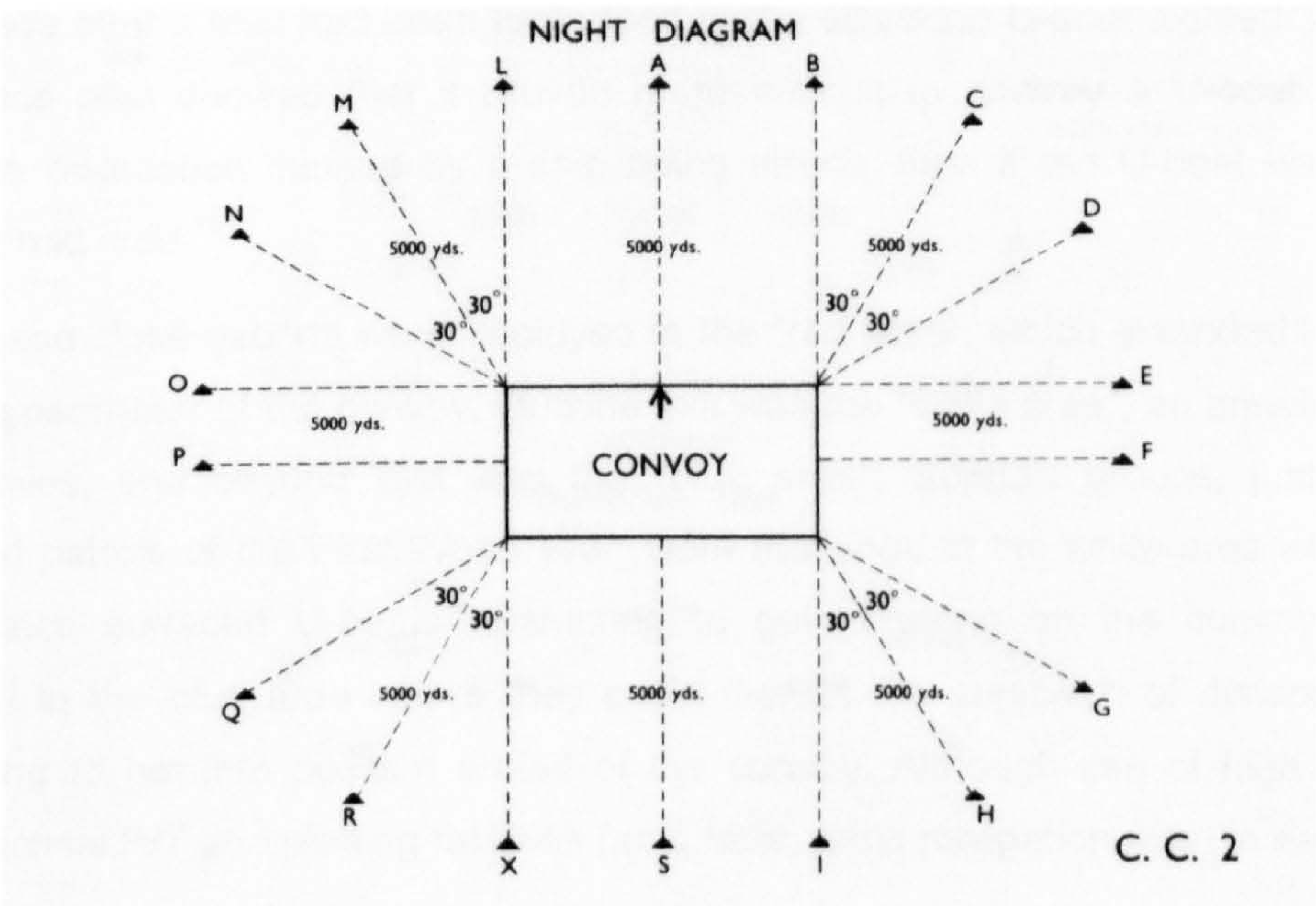
These methods of detection and attack were only of use, however, if the escorts could be stationed around fleets and convoys in such a way as to maximise their chance counterattacking a U-boat before it fired, or of locating it after a merchant ship was struck. The disposition of escorts was laid down in anti-submarine screening and escort diagrams. Initially, adequate tactical instructions did not exist to cover the most likely event of having to respond after the U-boat had attacked and individual escort group Senior Officers initiated their own procedures. Gradually, with the formalization of the training and tactical developments organization (especially at the Western Approaches Tactical Unit and at sea centred around HMS *Philante*), the situation improved and led to the issue of voluminous tactical manuals.[146] The emphasis here will be on the protection of convoys which was the more onerous task. Station-keeping in an ocean convoy was easier if the merchant ships were arranged in short columns on a broad front. Thus, with columns spaced 1,000 yards apart, and the individual ships within the columns 400 yards astern of each other, the overall size of a convoy of a typical 60-ship convoy was about 1-2 miles in depth and 6 miles in breadth (though later in the war, with the increasingly inexperienced merchant officers, the distance between columns was doubled to give greater safety).[147] U-boats could fire from 5,000 yards, and this range defined the torpedo danger zone (TDZ) around the perimeter of a convoy, the circumference of which was advanced on the convoy's track to allow for the torpedo running time.[148] The limited underwater speed and endurance of a U-boat meant that it could only reach a firing position from a relatively small distance to the left or right of the convoy's front. This distance increased if the U-boat was further ahead of the convoy. The starting points, therefore, for a U-boat to close to a firing position were described by the LLSuA (which were tangents to the TDZ) and angled outwards at about 30° for a 9-knot, fast convoy {*Plate 12*}. The angle would be larger for a slow, 7-

[146] Llewellyn-Jones, 'The Pursuit of Realism,' pp. 219-239.
[147] Arnold Hague, *The Allied Convoy System, 1939-1945: Its Organisation, Defence and Operation* (Annapolis, Maryland: Naval Institute Press, 2000), pp. 5, 10 and 25-26.
[148] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Article 35; 'A/S Screening,' Part 3, 'Conduct of Anti-U-Boat Operations,' CB4097(3)(44), June 1944, NHB, paragraphs 401-403.

Plate 13: ACI Convoy Diagrams for Day and Night, 1944

(Admiralty Convoy Instructions)





knot convoy but much smaller against a fleet steaming at 15 knots.[149] The high speed of U-boats on the surface meant that, in principle, they could approach from much wider angles to an attack position, though the use of high speed could make them more visible by creating a large wake.

The distance across the front of a convoy, from which a U-boat could approach submerged was too large for the available escorts to sweep with asdic, even if they zig-zagged around their stations. Against a surfaced U-boat better radar cover was possible, provided the sea was not too rough.[150] A/S vessels were disposed on "Escort Diagrams" optimized to frustrate a U-boat's approach and position the escorts to be able to take offensive action against U-boats that had got into a firing position. Thus escorts were placed 1½-2 miles ahead and on the bows of the convoy to intercept approaching U-boats, and 1 mile on the quarters from where they could close the position from which the U-boat attacked, or to attack those retreating after a torpedoing {*Plate 13*}. These distances gave the best compromise between keeping the escorts as close as possible to each other (thereby increasing the chance of detecting a U-boat trying to penetrate the defences, and providing mutual support between escorts), and the need to maintain as much "fighting room" as possible for offensive action against incoming U-boats. It was noted from operations that the great majority of A/S contacts were made after a ship had been torpedoed or the attacking U-boat sighted. However, experience also showed that it proved more difficult to destroy a U-boat after the inevitable dislocation caused by a ship being struck, than if the U-boat was caught before it had fired.[151]

These close escorts were deployed in the "red area", which extended to 6 miles from the perimeter of the convoy. Outside this was the "white area", an annulus from 6 to 12 miles, and beyond that was the "blue area". Support groups, just like the extended patrols of the First World War, were stationed in the white area where they could catch surfaced U-boats attempting to gain bearing on the convoy. Aircraft operated in the blue area where they could disrupt the approach of distant U-boats attempting to get into position ahead of the convoy. Although use of high definition radar, tactical R/T and plotting facilities (and, later, radio navigation aids) in escorts had

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[149] 'A/S Screening,' Part 3, 'Conduct of Anti-U-Boat Operations,' CB4097(3)(44), June 1944, NHB, paragraphs 401-405 and Figure 1.
[150] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Articles 30-34.
[151] 'Anti-Submarine Protection of Convoys,' A/Commander Harvey Newcomb, A/S 121/1/3, 5 May 1943, NAA(M): MP1049/5, 2026/12/537. Newcomb, an interwar A/S specialist, drew his information from the Admiralty's *Monthly Anti-Submarine Report* (as well as personal contact with Admiralty staff).

dramatically improved during WWII, the integration of the systems was still primitive and thus the co-ordination between ships (and aircraft) was still prone to confusion in poor weather or at night. Thus with these tactical zones, physical separation was enforced which reduced the chance of tactical confusion. Of course, the area boundaries could be breached when units were pursuing a U-boat.[152]

Tactics on Gaining Contact

Allied operational experience showed that a single A/S vessel was capable of dealing with a U-boat in good asdic conditions. However, in difficult asdic conditions, or when the water was disturbed from attacks a U-boat could easily escape. A second A/S vessel could help by maintaining asdic contact on the U-boat and thus resolve false echoes from ship's wakes or Squid and depth-charge explosions. Since the asdic and attack ranges were relatively short, the whole action took place in a relatively small area, any additional escorts served little purpose and tended to get in the way. They usually stood off at a short distance, patrolling around the action area and covering the U-boat's escape routes.[153] The two close-in ships manoeuvred so that their bearings relative to the U-boat were 90° apart. This helped ships avoid putting their wakes (and thus confusing asdic echoes) between the U-boat and their consort and, if the U-boat tried turn bow or stern on to one escort, it exposed its beam aspect to the other, so at least one escort had a good asdic echo. In a heavy sea, the pair would try to maintain the weather gauge, which lessened the effect of quenching (to say nothing of the fatiguing effect on the crew of the ship's motion), and reduced the danger of the ships inadvertently drifting downwind and out of contact. Asdic performance was usually better too, because transmitting downwind produced less pronounced surface reverberations from the waves. U-boats, for their part, would often try to make ground to windward.

The most modern escorts were fitted with a semi-automatic plotting table on which tactical information was mapped out though it did not allow for tidal movement or ship's drift due to the wind and sea, and the U-boat would, therefore appear to "drift" upwind. Nevertheless, soon after gaining contact, it was possible to calculate an estimate of the U-boats course to within ±30° and the speed within a knot or so. Because the plot kept a record of the U-boat's movements, if the ship lost contact

[152] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Article 38; 'Remarks on *Philante* Exercises, 29 July 1944,' W.H. McCrea, DOR/44/60, 3 August 1944, ADM 219/142.
[153] 'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2, paragraphs 285-296; 'US Fleet, Anti-Submarine and Escort of Convoy Instructions (BUSCIs),' FTP 223A, January 1945, File 79/532, DHH, p. 1-60.

during the final stages of an attack it was possible to estimate the time to fire. The plot also gave the Senior Officer (SO) of the Escort an overview of the tactical situation, from which he could plan more extensive lost-contact procedures, especially at night or in conditions of poor visibility.[154] Even though the U-boats could only travel underwater at a relatively slow speed, when contact was lost the area to be searched expanded at an exponential rate, being proportional to the square of the U-boat's speed. Given the comparatively slow search rate of the asdic, rapid action was needed if the U-boat was not to slip away. Immediate lost-contact procedures included "Search Scheme No. 1", which consisted of an all-round asdic sweep by each ship steaming at 7 knots on the last known mean course of the U-boat. While this was being done the SO would signal the action to be taken if contact were not regained.

Depending on the number of A/S ships present, he could order a "Square Search", commonly known as an "Observant", where the escorts were equally spaced and followed each other round the square. With more escorts the SO could order a "Box Search" where ships steamed in line abreast round the square. The idea of these searches was for the A/S ships to pass each point on the square often enough, so that the U-boat could not cross the perimeter without coming within asdic range of one of the escorts.[155] Alternatively, in "Search Scheme No. 2" the ships swept through the U-boat probability area twice in line abreast 2,000-3,000 yards apart. It was possible, in average asdic conditions with a working range of, say, 1,500 yards, to search a box about 4½ miles square in 35-45 minutes. To escape the U-boat would have to make a speed of at least 3 or 4 knots, at which speed she might betray her presence by producing sufficiently loud HE. If contact was still not regained, an expanding "Box Search" could be ordered, in which the legs of the search were adjusted so that the search would follow a vignot spiral formed from the locus of all the intercept points which could be reached by the target and the searching force for various U-boat escape headings.[156] This was the search concept favoured by the Americans. However, British experience suggested that greater probability of success could be achieved if some limits were placed on the likely escape courses. Searching was therefore focussed on a relatively narrow sector in the form of a "Gamma Search", consisting of escorts sweeping in line abreast at right-angles across the U-boat's assumed escape course. The Gamma search was started at a point on the U-boat's

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[154] 'Detection, Attacking, Hunting,' CB4097(2)(42), December 1942, Box 468, RG 38, NARA2, paragraphs 193 and 308-309.

[155] 'Air and Surface A/S Searches and Striking Forces,' Part 4, BR1679(4) [formerly CB4097(4)(44)], June 1944, NHB, p. 20.

[156] 'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2, paragraphs 343-344 and 375-378.

anticipated track equal to its "furthest on" predicted position (based on the U-boat's expected maximum transit speed) and continued until the "furthest back" position (based on a prediction of the slowest U-boat transit speed) passed through the patrol line. The zig-zagging escorts were stationed three miles apart in daylight and five miles apart at night, when the U-boat was more likely to attempt to escape using its high surface speed. Two A/S vessels were required to patrol a lane 10 miles wide, and four for a 30 mile lane, though, in practice, the "Gamma Search" never succeeded in locating a U-boat.[157] This illustrates the difficulty of locating a submarine if A/S ships could not arrive at the datum very soon after it was created, and the "Gamma Search" was withdrawn from the tactics books in 1945.

By 1943 with the growing power and numbers of escorts, particularly those in support groups, came the freedom to hunt attacking U-boats to destruction. These hunts usually took some time and required persistent, deliberate attacks by the A/S vessels. However, for actions close in to a convoy, escorts had to rapidly appreciate the level of threat to the ships being escorted. If the U-boat was in a position to carry out a torpedo attack, the escorts would respond with an immediate counter-attack, emphasizing speed rather than accuracy. This was designed to put the U-boat off his aim and to seize the initiative so that more deliberate and deadly attacks could be mounted. Squid or depth-charges were useful in this regard. If the initial contact was more distant, and there was plenty of fighting room, the escort could afford to make the first attack a deliberate one. Any of these attacks by escorts always risked the U-boat deliberately targeting them with a torpedo, a risk unhesitatingly accepted if the ship being screened was a fleet unit or a troopship. Against the conventional straight-running weapons, provided the torpedo was detected, the escort could turn towards the incoming torpedo which substantially reduced the chance of it hitting. When Captain C.D. Howard-Johnston, Director of the Anti-U-Boat Division (DAUD), was asked how far a Captain should hazard his own ship when attacking a U-boat, remarked that

> "There is no risk yet. The U-boat is out to sink merchantmen...[and the escorts] are a confounded nuisance to its Captain, not a target. When the first escort vessel is torpedoed deliberately you will know that the Hun is beaten and the war is won. Everything else after that date is just a mopping up operation."[158]

Howard-Johnston accurately foretold (as Captain Edelsten had done earlier) the introduction in the autumn of 1943 of the Gnat homing torpedo. In fact, the British already made a fairly detailed assessment of the way Gnat operated from Special

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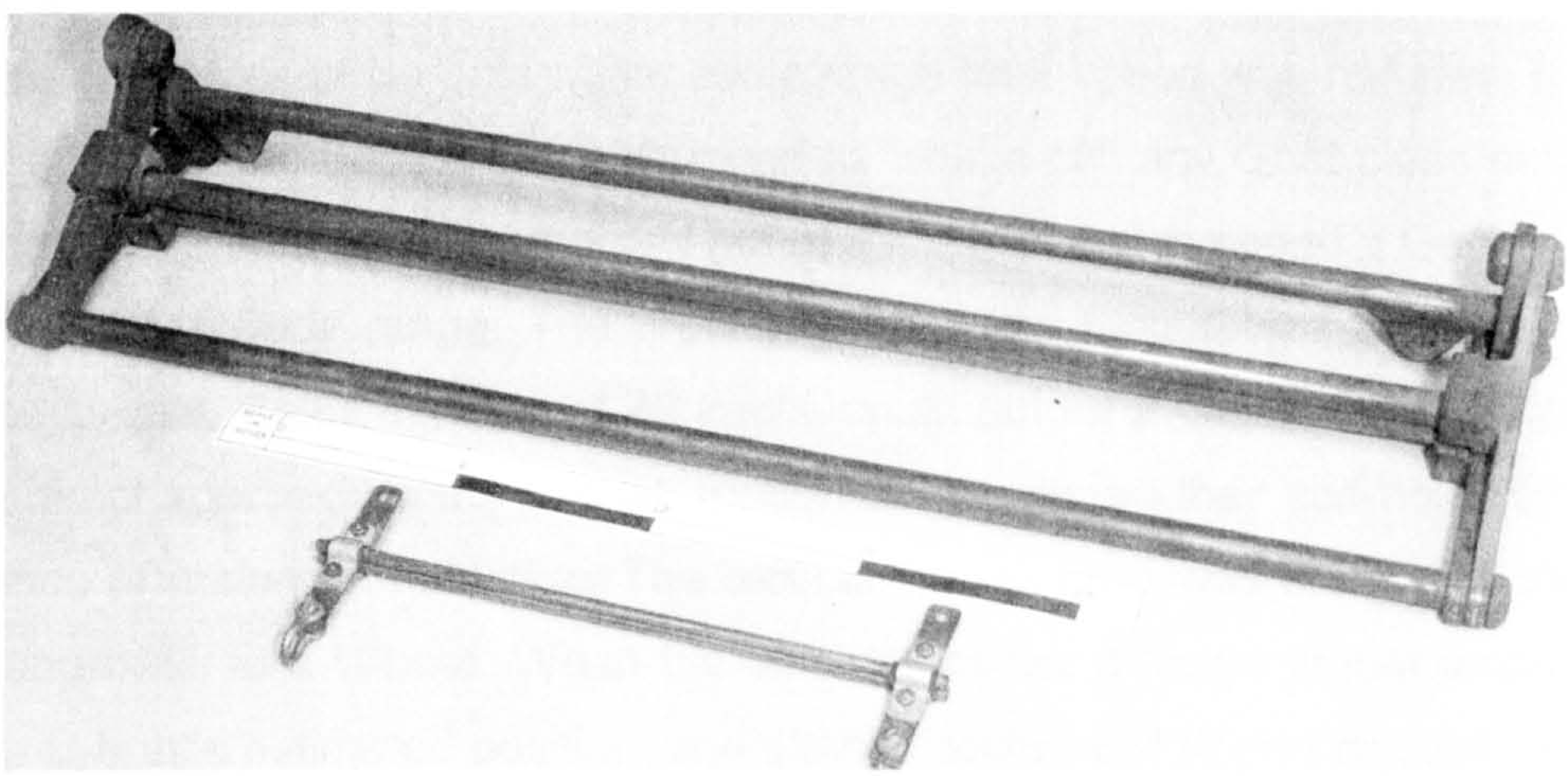
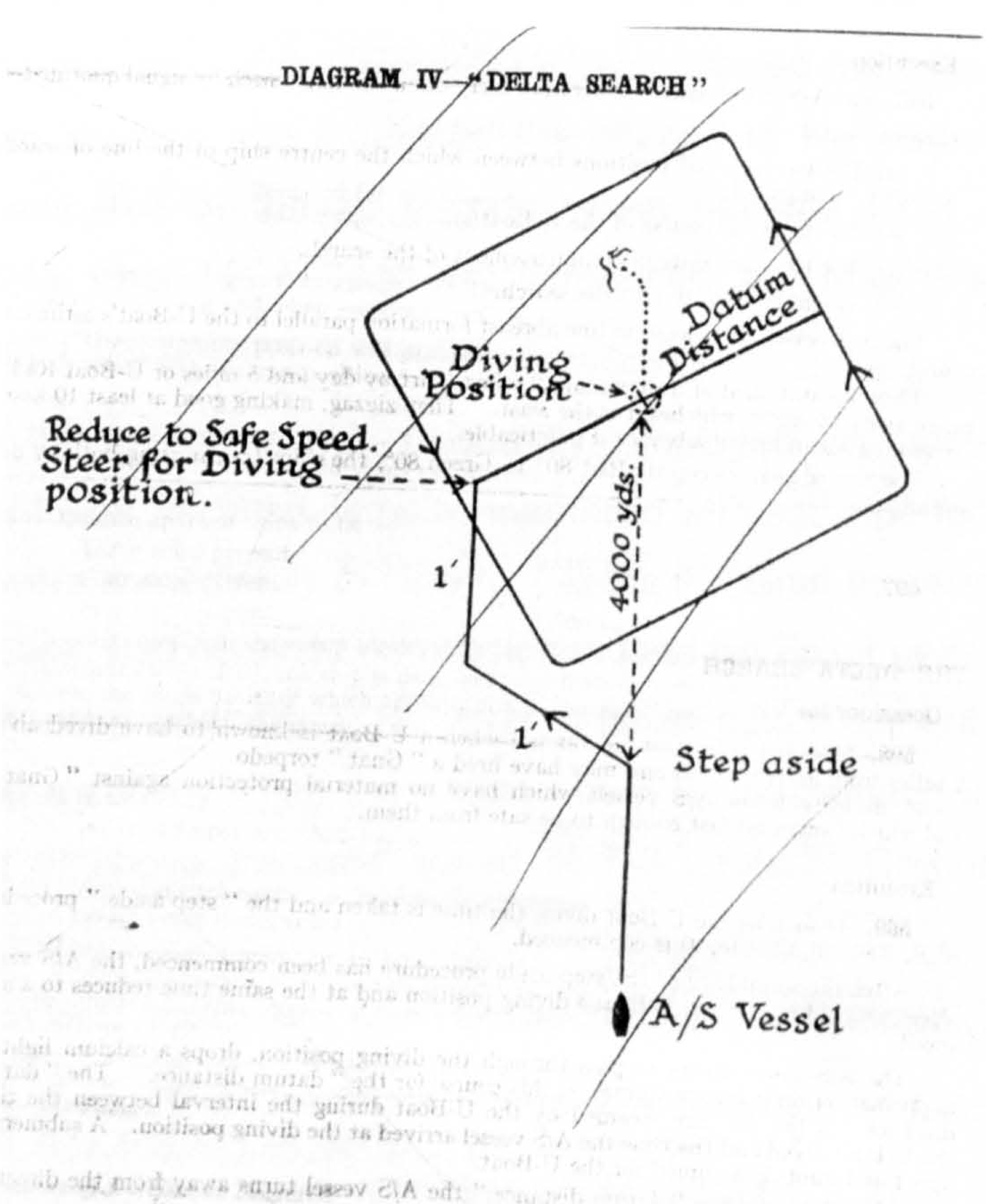
[157] 'Operation "CW": Analysis for NW Approaches, 25 August – 17 October 1944,' W.H. McCrea, DNOR, 1 December 1944, ADM 1/17653, p. 16.
[158] Quoted in: D.A. Rayner, *Escort: the Battle of the Atlantic* (London, William Kimber, 1955), p. 155.

Plate 14: Foxer and Step-Aside

'Acoustic Measurements of Foxers,' Mine Design Department, M.S. Summary No. 982/44, 7 June 1944, ADM 253/650; "Delta Search", 1944, B.R. 1679 (3) (44), 'Conduct of Anti-U-Boat Operations: Part IV, Air and Surface A/S Searches and Striking Forces' A/S. W. 3078/43, Anti-Submarine Warfare Division, Admiralty, June 1944, ADM 234/293.



Foxer



Step-Aside (with Plan "Delata")

Intelligence aided by an understanding the techniques employed in the similar American Mk XXIV Mine (an air launched homing torpedo).[159] Countermeasures were therefore developed rapidly. Escorts were soon equipped with the towed "Foxer" made up of two pipe noise makers (PNMs), each consisting of two pipes connected together at their ends but allowed to vibrate against each other as they were towed through the water {*Plate 14*}. The resultant noise was some 10-30 times noisier than the ship's propellers, and would thus seduce the Gnat away from the ship. So, ships closed the U-boat as fast as possible until within asdic range their speed was reduced, the Foxer tripped, and a single depth-charge dropped to "shake-off" any Gnat close astern. The remainder of the hunt was then carried out at 8 knots at which speed a Gnat could only home from very close range. The problem with these tactics was the time taken to close the U-boat. Ships capable of 25 knots, could outrun a Gnat, and could therefore make a direct approach to the U-boat, though at high speed their self-noise would limit the chance of making a detection. The tactical compromise was the use of the "Step-Aside" approach to a U-boat. When the escort reached a range of just under 3 miles from the U-boat's estimated position, she altered course 60° to port or starboard, while maintaining her best speed. This new heading was held for three minutes which would laterally separate the escort from the Gnat's track outside to torpedo's detection range. The escort then again altered course to make a direct track towards the U-boat's position.[160] The diversion of the "Step-Aside" also slowed the escort's approach to the U-boat's datum position and increased the chance of her escape. A contemporary assessment was that of the 24 escorts which became Gnat casualties between September 1943, when the weapon was introduced, and May 1944, only two were hit while taking anti-Gnat counter-measures.[161]

Captain Walker, who was frequently employed on hunter-killer operations, disliked use of Foxer because its noise interfered with asdic performance. He directed that all ships were immediately to slow to 7 knots if a Gnat threat was imminent and in the spring of 1944, had obtained permission to land his Foxer gear prior to carrying out independent hunting operations. However, Walker saw the merit in using the Foxer while escorting a convoy when the escort would be zig-zagging ahead of the convoy and steaming at above the safe speed of 7-8 knots.[162] Gretton, too, disliked the

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[159] 'Some Operational Implications of a Homing Torpedo,' L. Solomon, Report 36/43, 1 June 1943, ADM 219/52.
[160] 'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2, paragraphs 380-381.
[161] 'Monthly Anti-Submarine Report, June 1944,' ADM 199/2061, p. 27.
[162] R. Whinney, *The U-boat Peril: An Anti-Submarine Commander's War* (Poole: Blandford, 1986), p. 127; Terrence Robertson, *Walker RN* (London: White Lion edn., 1975), p. 142.

interference with the Asdic the Foxer caused and did not stream it in his destroyer, though it was occasionally used by the slower ships of his group.[163] Once in contact, escorts in close action could be embarrassed by the trailing Foxers as they manoeuvred to attack the U-boat.[164] The primary aim, Walker stated, was '...to destroy U-boats, particularly those which menace our convoys.' This object was amplified in his standing orders for the Second Escort Group (EG2):

> Our job is to kill, and all officers must fully develop the spirit of vicious offensive. No matter how many convoys we may shepherd through safely, we shall have failed unless we can slaughter U-boats. All energies must be bent to this end.[165]

As a result he was willing to take risks with his ships in order maximise the chance of a U-boat kill. He was convinced that defence for support groups against the Gnat

> ...must lie in tactics and not Foxers, which greatly reduced the chance of killing U-boats, especially in vile Asdic conditions when echoes were poor and faint. He considered that occasional casualties must be accepted, but emphasised that Gnats could not home on sloops at low speed. The Commander-in-Chief agreed – in the case of experienced groups.[166]

Admiral Horton, Commander-in-Chief, Western Approaches, understood the dilemma for Senior Officers and ships' captains. 'It *is* a game, this U-boat struggle,' he remarked,

> – the "Gnat" is a nasty snag and delays the approach – all ships hit to date have not completely carried out instructions [careful approach to the U-boat], but in the heat of the moment the offensive spirit of the escort vessels takes charge, and it is hard to blame them severely.[167]

The aggressive spirit amongst A/S practitioners is evident from these views.

Beating the Submersible

The foregoing account suggests, at face value, a rather banal tactical pattern. Indeed, at a very early stage in the Battle of the Atlantic it was noted that the German '...tactics conform to a stereotyped pattern so that counter-measures may be uniformly applied.'[168] The British counter, however, was the complex interaction of tactics on three main fronts. Firstly, convoy made it more difficult to the U-boats to find their

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163 Peter Gretton, *Convoy Escort Commander* (London: Cassell, 1964), p. 166.
164 Alan Burn, *The Fighting Captain: Frederick John Walker and the Battle of the Atlantic* (London: Leo Cooper, 1993), p. 113.
165 'Second Support Group Orders,' Captain F.J. Walker, CB, DSO, 19 June 1943 (still extant, with amendments, 9 March 1944), File PGC 5, IWM P432, p. 2. [emphasis supplied]
166 Alan Burn, *The Fighting Captain: Frederick John Walker and the Battle of the Atlantic* (London: Leo Cooper, 1993), p. 142.
167 W.S. Chalmers, *Max Horton and the Western Approaches* (London: Hodder and Stoughton, 1954), p. 212.
168 'U-boat Methods of Combined Attack on Convoys, 1 February to 31 October 1941,' Naval Section [GC&CS, Bletchley Park], ZIP/ZG/116, 10 November 1941, ADM 223/1, p. 20-21.

targets, and most convoys escaped detection altogether. Secondly, the enemy relied on the use of the surface, for searching and tactical mobility (which was severely limited when the U-boat submerged). Thus aircraft both on area searches and patrols in the vicinity of convoys could locate U-boats, sometimes destroying them, but at least forced them to dive. Surface support groups, patrolling at a distance round a convoy, did the same. Thirdly, the extensive use of radio by the U-boats gave the British the ability to locate U-boats in the wide expanse of the ocean. Aircraft on area patrols could be more effectively tasked, threatened convoys could be reinforced with surface and air escorts, and individual U-boats close to convoys could be forced to dive and often attacked. The results were adduced by the Government Code and Cypher School, Bletchley Park, at the end of the war. They wrote that by May 1943:

> The nature of the problem facing the U-boat Command had...changed. Whereas in the first three of four years of the war the effectiveness of the arm was limited by inadequate numbers, there was now almost an *embarras de riches*. The U-boat Command found itself in control of a fleet of over four hundred boats, which it was unable to deploy fully, as the types of which it was composed were no longer suited to contemporary operational conditions. The expectation of life of a U-boat joining the operational fleet in the third year of war (September 1941 to September 1942) had been about eleven and a half months; in the following year, a 500-ton boat might expect to survive only about eight months....[169]

Much of this was achieved by improved use of technology but success also depended on the development of appropriate tactics. Nor should the latter be seen as the imposition of some dogma in a "one-size-fits-all" formula. Notwithstanding that the enemy's tactics were largely stereotyped in concept, the vagaries of individual performance, weather and the scale of forces pitted at any one moment, meant that particular anti-submarine actions were each unique events and required considerable skill on behalf of the proponents. That said, the reinforcement of threatened convoys was an idea that had served the Royal Navy well since the eighteenth century in a very different technological era.

It was impossible for every convoy to be given an escort capable of countering the heaviest pack attack. If adequate intelligence were available, it ought to be possible to reinforce threatened convoys. Aircraft were able to be rapidly re-deployed in this manner, but, valuable though they were, they were not the whole answer, for additional surface escorts were needed too. The progressive increase in the size of convoys over the winter of 1942-43 and the lengthening of the convoy cycle helped to relieve the pressure on the direct escort groups, and free vessels to form support groups. These

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[169] 'The German Navy – The U-Boat Arm,' Lieutenant H.M. Anderson, RNVR, Lieutenant Commander R.J. Goodman, RNVR, and Commander A.M.S. MacKenzie, RNVR (ed.), GC&CS Naval History, Vol. XVII, c. December 1945, NHB, pp. 219-220.

could then be used to reinforce threatened convoys. The direct linkage between these tactical moves is not clear, for the support group requirement had already been established in 1942 on tactical grounds, but it was only in February 1943 that Admiral Edelsten, Assistant Chief of Naval Staff (U-boats & Trade) (ACNS(UT)), was satisfied that there were sufficient escort vessels to form support groups on a permanent basis (aided by the temporary cessation of the Arctic convoys). The escorts strength for each convoy was, in theory, calculated using the formula of three escorts per convoy, plus one extra for every ten ships in the convoy, provided air escort was also available. It was emphasized by the Naval Staff prior to the Casablanca Conference in early January 1943, that:

> Without air escort this provision of escorts is totally inadequate against wolf-pack tactics on the scale that we must now expect. In fact, it may be said that, without air escorts, convoys attacked need at least one escort for every U-boat attacking – and at present "packs" may well consist of up to 15 U-boats. It is therefore assumed that all convoys will:–
>
> either
>
> (i) be so routed as to be able to receive escort by shore-based aircraft, or,
>
> (ii) be accompanied by an escort carrier.[170]

Initially, the escort carriers, or CVEs, were employed by the British as an integrated part of the convoy escort, where they provided not only A/S air cover but also fighter protection on some routes closer to enemy controlled coasts. Only later were they briefly used on more offensive operations.[171]

The value of the support groups, like air cover, was in harassing and attacking U-boats that were attempting to shadow or gain bearing on the convoys, and their ability to conduct prolonged hunts of U-boats that made attacks. A/S ships and, especially, aircraft could profitably be used in distant patrols around the convoys where U-boats were most likely to be on the surface. The analysis of support group operations (and air escorts) undertaken in the middle of 1943 illustrate the point. The attacks on U-boats by the close escort and the supports for Convoy SC130 (the last convoy to be seriously threatened by U-boat pack attack in Spring 1943) show that half of the attacks were as a result of surface escorts either joining or sweeping at a distance round the convoy. Overall, during the 10 hunts by close escorts and support group ships the initial detections were, in one instance result of a high-frequency direction finding (HF/D/F) contact, two by asdic, two by radar and five were sightings of U-boats. Aircraft contacts

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[170] 'A/S Warfare in Relation to Future Strategy, Memorandum by the First Lord of the Admiralty,' War Cabinet, Anti-U-Boat Warfare, AU(43)1, 5 January 1943, ADM 1/14793, p. 10.
[171] 'Instructions for the Operation of Escort Carriers,' Admiral Max Horton, Commander-in-Chief, Western Approaches, Memorandum No. WA.0756/36, 7 February 1943, ADM 1/13081.

were between 10 and 30 miles from the convoy and in every case the contacts were obtained visually.[172] An earlier DNOR study had shown that Groups had spent 31% of their sea time supporting convoys during the period of the last major U-boat campaign on the ocean convoy routes between September 1943 and January 1944. They had spent 21% of their sea-time in U-boat probability areas and 48% in transit, as would be expected in supporting the widely spaced ocean convoys.[173] The other points which emerged from the analysis of these support group operations in May and June 1943, was that the groups spent only about one tenth of their time at sea with shadowed convoys (though convoys received support for about 40% of the time they were being shadowed). Lest these figures seem low, it should also be noted that only about 15% of the close escorts' sea time was with shadowed convoys. What is also significant is that the support groups spent between 50 and 60% of their time on passage.[174] This rather high figure might be viewed alongside the time spent by hunting groups early in the war accused by some historians of "fruitlessly" scouring the seas for enemies. The operations of the support groups also demonstrated the increasing probability that aggressive U-boats would suffer fatal consequences.

The *Admiralty Convoy Instructions* (ACI's), reiterated that the primary objective of the of convoy escort was: "The safe and timely arrival of the convoy at its destination...." This aim was echoed precisely by the USN instructions. Though the British instructions were revised by one of the most aggressive Escort Group Commanders, Commander P. Gretton, many contemporary A/S practitioners took the "safe and timely arrival" objective as imposing too great an emphasis on the defensive.[175] The criticism seemed compounded by the British instructions which went on to say that '...attempted evasion may attain the primary object....' However, this edict was then conflated by

> ...the need for reducing the time spent in dangerous waters and desirability of reaching an area of air cover must be considered when planning evasive measures.[176]

[172] 'Analysis of U-boat Operations in the Vicinity of Convoy SC130, 18-21 May 1943,' Anti-U-boat Division, Admiralty, 15 July 1943, ADM 199/2020.
[173] 'Notes on Support Group Operations, September, 1943 – January, 1944,' [Leon Solomon], CAOR, OIC/SI.919, 6 April 1944, ADM 223/172.
[174] 'An Analysis of the Operation of Support Groups in the North Atlantic (Period 14 April – 11 May 1943),' Anti-U-boat Division, Admiralty, 15 June 1943, ADM 199/2020; 'An Analysis of the Operation of Support Groups in the North Atlantic (Period 5 May – 12 June 1943),' Anti-U-boat Division, Admiralty, 15 July 1943, ADM 199/2020.
[175] Lieutenant Commander John Guest, RNVR, Telephone Interview, 14 May 2001.
[176] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Article 1.

Those, who in the spring of 1943, condemned these instructions at the height of the Atlantic Battle, did so with little idea of the true nature of the "Nelsonial" aggressive spirit. This philosophy of offensive action in the Royal Navy certainly extended back to the days of the Elizabethan Navy. But, as Corbett notes (albeit while discussing Fleet actions),

> ...the maxim of "seeking out" for all its moral exhilaration, for all its value as an expression of high and sound naval spirit, must not be permitted to displace well-reasoned judgement.[177]

The critics also did not see, as many of the more experienced officers did, that the lack of sufficient high-performance A/S vessels in relation to the threat and the size of the escort task, meant that for much of 1941-42, the Royal Navy was obliged to remain on the defensive. Ultimately, the Royal Navy understood that "defensive" and "offensive" A/S operations were not alternatives but were combined in a symbiotic relationship. Simply carrying out offensive operations randomly, as noted for an earlier era, was '...almost bound to end in a blow in the air, which not only would fail to gain any offensive result, but would sacrifice the main defensive plank....' However, the Royal Navy did not follow an "offensive" trait simply because its apparent opposite, the "defensive", was a negative form of warfare, or that the offensive was positive and led to glory. Only the offensive would, ultimately, lead to victory, but that offensive, however, had to be based on a sound defence. Convoy had often been seen as a "defensive" strategy. Corbett modified the idea that the defensive was synonymous with passivity, in fact it was imbued with '...an attitude of alert expectation.'[178] Indeed, convoy was described by Admiral Sims, Commander of the US Naval Forces in Europe during the First World War as "a purely <u>offensive</u> measure".[179] This is echoed by other writers, but although they and Sims rather overstate the case, the point is clear: convoy provides for a concentration of A/S assets, well placed to destroy attacking submarines, and the aggressive spirit is maintained by offensive action, or at least the thirst for it. Howard-Johnston, as an escort group commander early in the war knew that, when resources were stretched: "Our business is to bring home the merchantmen. The sinking of the enemy is only a secondary consideration at this stage of the war. Our turn will come later."[180]

That such criticism should re-emerge in the spring of 1943 is somewhat surprising, given the contemporary shore-side teaching at the Western Approaches

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[177] Julian Corbett, *Some Principles of Maritime Strategy* (Naval Institute Press, 1972), pp. 172-173.
[178] Corbett, *Some Principles*, pp. 29-30 and 171-172.
[179] 'A Study of the Philosophy and Conduct of Maritime War...,' MLJ, p. 20 [emphasis supplied].
[180] D.A. Rayner, *Escort: the Battle of the Atlantic* (London: William Kimber, 1955), p. 87.

Tactical School (WATU), in Liverpool, and the advanced tactical training of formed escort groups at sea based around *Philante*. Captain G.H. Roberts, at WATU found it necessary to issue, under the Commander-in-Chief, Admiral Sir Max Horton's signature, additional guidance on the interpretation of these tactical instructions. In essence, Roberts pointed out, the offensive school saw the issue in terms of:

> Failure to destroy the U-boats will enable their numbers to increase to such an extent that we shall eventually be overwhelmed by sheer weight of numbers. The morale of the crews will remain at a high level unless a reasonable number of casualties are inflicted, and as a result their offensive spirit will be sustained at a high pitch.

On the other hand, Roberts noted, the defensive school thought that:

> If trade can be maintained by the continued passage of convoys in comparative safety, the war can be won by other means. Furthermore, the continued failure of U-boats to achieve any great measure of success will sap their morale and weaken their determination.[181]

Both sides of the argument contained valid points. As the war turned out, the defensive approach was largely forced on the Allies (at least in 1941-42) by the lack of escorts for the expanding convoy system. They were simply unable to take the offensive, without seriously jeopardising the safety of convoys. Coastal Command had been faced with a similar situation as a Cabinet Committee appreciated in 1941

> ...the great potential value of aircraft, freed from routine patrols on convoys, as a "harassing force" to take the offensive against U-boats and would welcome the provision of such a force in the Western Approaches. But, with our primary object of the safe and timely arrival of our shipping in mind, it is believed that such a force can only be justifiably instituted when the close protection of our convoys has been made reasonably sure.[182]

On both sides of the Atlantic it was appreciated that the matter was '...largely a question of numbers.'[183] The U-boat was very difficult to locate in the open ocean unless precise and timely intelligence was available. More effective use could be made of A/S forces by deploying them where the enemy also had to concentrate in fairly large numbers, that is, off his bases and around convoys. The crux of the philosophy was to bring A/S forces into contact with the enemy so he could be destroyed. As the Admiralty and Commanders-in-Chief, through ACI's, reminded Escort Commanders,

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[181] 'Western Approaches Tactical Policy,' Admiral Max Horton, Commander-in-Chief, Western Approaches, No. WA.0609/45, 27 April 1943, File 307-0, Vol. 11940, RG 24, NAC.
[182] 'Report of Committee on the Winter Campaign of 1941-1942 in the Battle of the Atlantic,' in, 'Monthly Anti-Submarine Report, April 1941,' DASW, CB04050/41(4), [May 1941], NHB, p. 10.
[183] 'Western Approaches Tactical Policy,' Admiral Max Horton, Commander-in-Chief, Western Approaches, No. WA.0609/45, 27 April 1943, File 307-0, Vol. 11940, RG 24, NAC; 'Anti-Submarine Measures,' E.J. King, Commander in Chief, United States Fleet and Chief of Naval Operations, FF1/A16-3(9), 19 May 1943, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

> ...it must be borne in mind that if enemy forces are reported or encountered, the escort shares with all other fighting units the duty of destroying enemy ships, provided this duty can be undertaken without undue prejudice to the safety of the convoy....[184]

But these instructions were not dogma: WATU taught,

> Senior Officers of Escort Groups have complete freedom to exercise their initiative under all circumstances, and it is not desired that they should be rigidly bound to comply with any of the diagrams of operation orders laid down in ACI's.[185]

Not the least reason for adopting such a policy was that, as the British readily appreciated, the enemy was bound to react to improved British tactics with changes of his own. Senior Officers were encouraged to be on the lookout for new methods employed by the enemy and to initiate appropriate countermeasures. As operational experience had amply demonstrated, the best insurance was provided by escort groups well organized, well trained, and well led by their own Senior Officer (SO). It was, ultimately, the SO, who drove the training of his group and created its general efficiency. The formal training organization, from the individual work-up base at Tobermory to the shore training at base ports and at WATU in particular, as well as the sea training with *Philante*, were valuable in providing the foundations of group efficiency. But it was the leadership of the individual Senior Officers who made the difference between effective and inefficient groups.

By the end of 1943 it was recognised by the British that the U-boats were rarely to be seen on the surface during the day as a direct result of Allied A/S countermeasures. The U-boats were thus able to substantially reduce the chance of being located, particularly by aircraft, but were denied the advantages of adequate reconnaissance, rapid communications and the ability to shadow convoys, and homing consorts onto the target. In particular, as the Western Approaches Command noted, U-boats were denied the '...mobility which enabled more distant U-boats to intercept a reported convoy.' These U-boat tactics had '...already greatly promoted the safe and timely arrival of the convoys, but they must inevitably give us fewer opportunities to destroy the enemy.' As a result, every opportunity was now to be taken to destroy U-boats. Support groups, and even portions of the close escort were to be detached after a convoy battle to return to the scene of the engagements '...for mopping up' operations. Unless A/S vessels encountered a U-boat in an immediately threatening position, when an urgent counter-attack was required, engagements were to be

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[184] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB, Article 1.
[185] 'Western Approaches Tactical Policy,' Admiral Max Horton, Commander-in-Chief, Western Approaches, No. WA.0609/45, 27 April 1943, File 307-0, Vol. 11940, RG 24, NAC.

deliberate with the object of destroying the U-boat. It was emphasized that standard depth-charge attacks provided ample warning to the U-boat of the moment of firing (because the attacking ship would pass roughly overhead at high speed). Against a deep U-boat, free to manoeuvre, these tactics were ineffective. Western Approaches pointed out that in

> ...the Hedgehog and in the Squid are combined the two attributes of precision and surprise which ensure its effectiveness in a deliberate attack. For a U-boat which is too deep for the Hedgehog, the "Creeping Attack", which has the same attributes, has recently proved on three occasions its deadly day accuracy.[186]

Standard depth-charge attacks on a deep U-boat were no longer seen as justified, other than for driving the U-boat deeper, so that a "Creeping Attack" could be used. The emphasis on the use of ATW would be valuable in the event of the enemy's high-speed U-boats becoming operational. On a wider scene the immediate problem of dealing with U-boats operating continuously submerged (let alone also capable of high underwater speed) was to re-focus British A/S doctrine on the balance between defensive and offensive tactics.

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[186] 'Battle of the Atlantic: Recent Changes in Enemy Tactics,' CSO(M), C-in-C, WA, Hush Message, 142141A December 1943, ADM 217/358. See Appendix 3.

Chapter 3: Elusive Victory: Countering the Schnorkel, 1944-1945

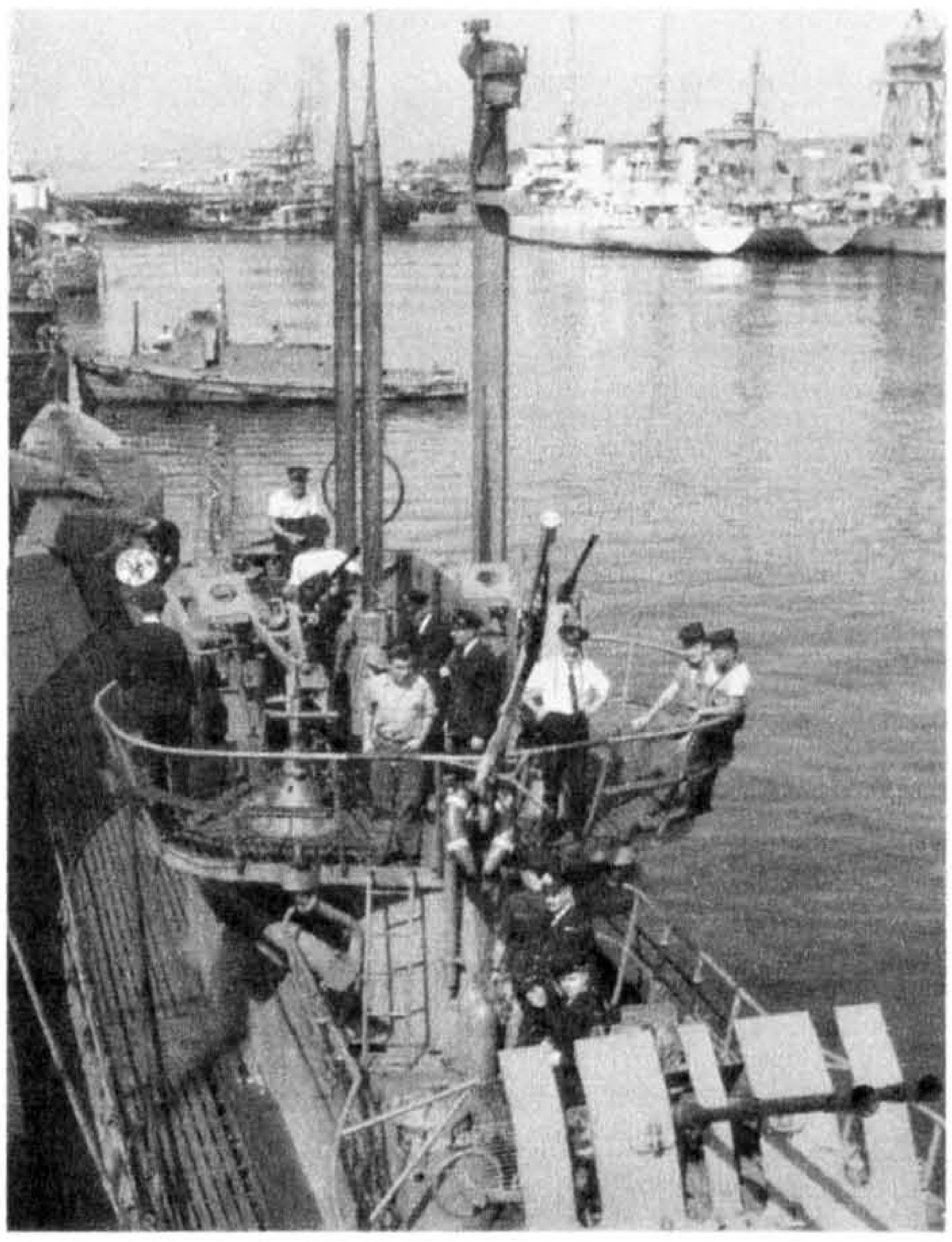
Introduction of the Schnorkel and its Effect on British A/S Operations

As has was observed in the last Chapter, the German Naval High Command became increasingly aware that despite the growing numbers of the U-boat fleet, individual U-boats were achieving fewer sinkings. Allied air power, particularly in the Bay of Biscay, was noted as having a major impact on the effectiveness of U-boats in making free use of the surface to move to, and within, their operational areas. Towards the end of 1942 the Germans began feverishly searching for ways to redress the situation which was becoming critical and their solutions would have a lasting impact on the conduct of A/S warfare down to the present day. One solution was to adapt their existing U-boats by fitting an extendable air intake to allow them to transit submerged at periscope depth, while drawing in air so that they could run their diesel engines and ventilate the boat. It was assessed by the Admiralty that this system, known as the "schnorkel", could be used in sea states up to 3-4 and would present only a small radar target that would be extremely difficult to detect by radar (or by eye) and made the U-boat practically invulnerable to air attack {*Plate 15*}.[187] At around this time, the British, too, had been considering the adoption of the schnorkel in the design for the "A" Class submarine, drawn up in October 1942, to counter the rapid improvement in radar performance. However, it was soon decided that the threat to British submarines did not warrant the adoption of "submerged dieseling", which brought with it operational limitations.[188] This was not the case for the Germans, who began a sporadic development of the schnorkel, and by late 1942, *U-448*, while working up in the Baltic, was fitted with an H-shaped, experimental type. Although the equipment achieved moderate success, it was removed and further sea trials temporarily abandoned. By December 1943 an improved design was being fitted to operational U-boats at St. Nazaire, with the first Baltic boats equipped and an instructional programme started in the following February. The enemy's priority was fitting U-boats in the Biscay ports as a

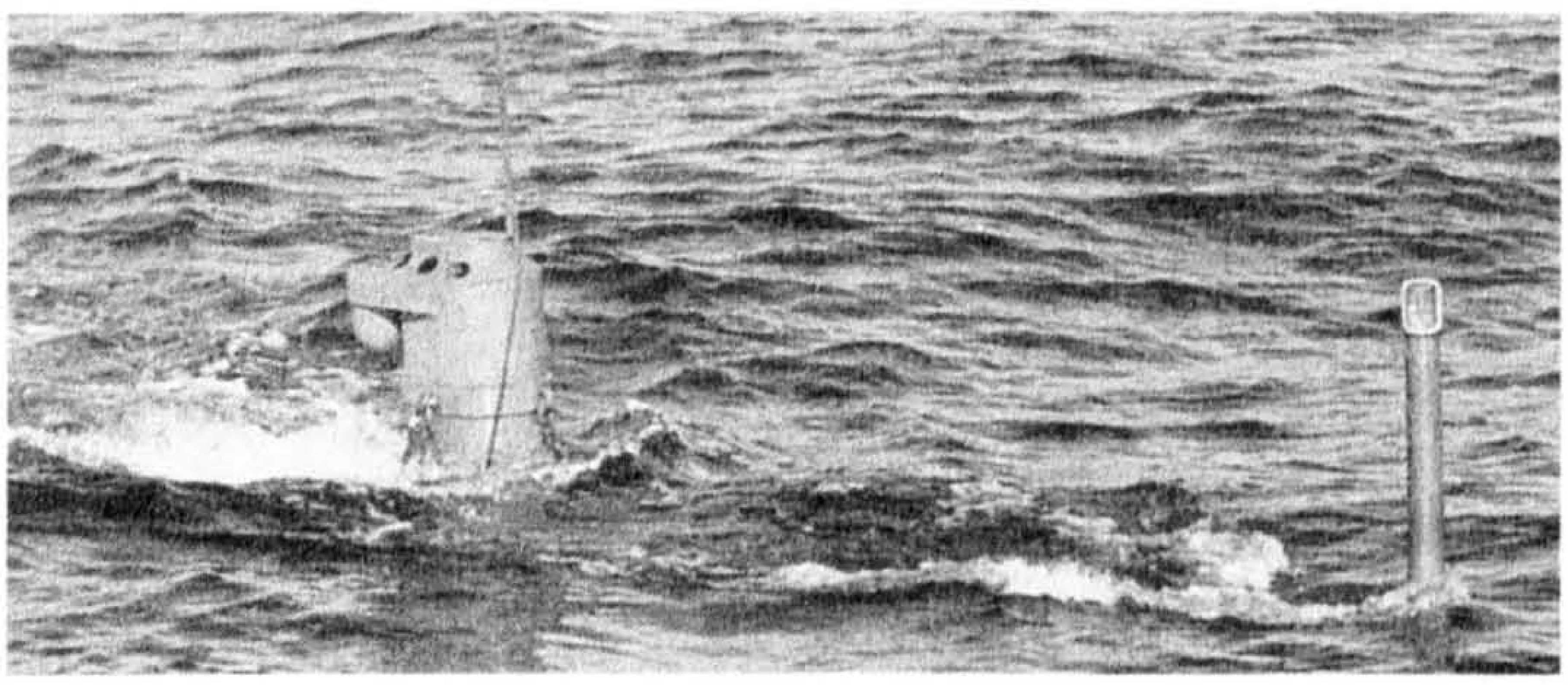
[187] 'Inshore U-Boat Operation,' Admiralty Message, CASO No. 6, DTG 252307A October 1944, NAA(M): MP1185/8, 1932/3/45.
[188] 'Records of Warship Construction, 1939-1945. The History of DNC Department,' Written 1945-46. Approved for issue by DSDE, 1981,' RNSM Box 5, p. 39.

Plate 15: Schnorkel

NAC PA-134173, DND PMR 94-096 and NAC PA-141384



U-boat with Schnorkel Extended



Dummy Schnorkel fitted to British Submarine

Effect of Schnorkel on Air Search (the Schnorkel is in the centre foreground) means of safely transiting the Bay *en route* to their Atlantic operational areas. Only later did the Germans realize that schnorkel boats would have an advantage in operations against an invasion of the Continent. The last boats to be fitted were those based in Norway, the first of which only appeared in early September 1944 (though not all Biscay boats had been fitted by that date). British interrogation of prisoners-of-war (PoW) revealed that by mid-August 1944 about one third of the Type VIIs and most of the Type IXs had been fitted.[189]

By February 1944, the Admiralty were anticipating that the enemy could be expected to operate U-boats close inshore, a change of tactics which the escorts had to be prepared to repel. That month, the first U-boat (*U-264*) fitted with schnorkel had been sunk in the Atlantic, though she appears to have been operating conventionally. By the end of February the Admiralty had deduced the true nature of the schnorkel and by May some attacks had been made on schnorkelling boats off the Guernsey coast. The first extensive experience with schnorkel boats was during the operations in support of the invasion of the Continent in June 1944. Those U-boats not fitted with schnorkel that tried to penetrate into the invasion area had been roughly handled and further attempts were abandoned. Within a fortnight, Professor Williams and Dr. Solomon of DNOR completed a rough analysis of A/S operations against the schnorkel-fitted U-boats in the Channel. They concluded that aircraft capability against these U-boats was about a fifth of that expected against their non-schnorkel cousins, and therefore the onus of dealing with schnorkel U-boats largely fell on surface A/S vessels. However, at first, they fared no better. Williams and Solomon calculated that escort groups should have made contact with each of the U-boats about 4 times, assuming the escorts were each able to sweep a path 3,000 yards wide, which was the performance to be expected in the Atlantic. However, actual results suggested that the individual escorts were only achieving a swept width of barely 600 yards. From Special Intelligence the OIC concluded that, when searching for U-boats using "Gamma" patrols, the support groups had probably passed directly over U-boats on about 10 occasions, but had made only one contact. The enemy, on the other hand, had detected 65% of the escorts which passed within about 3 miles. The U-boats were using their hydrophones and '...it was the sound of the foxers which was first

[189] 'U-boat Situation, Week Ending 11 September 1944,' Captain Rodger Winn, RNVR, OIC/SI.1078, n.d., ADM 223/172; 'Schnorkel,' Appendix "A" to 'Report on German and Our Strategy and Tactics: Anti-Submarine Warfare (Section C, Sub-Sections 1-4),' Wing Commander T.V. Stokes, RAAF, Overseas Headquarters, London, 61/50/Air, 14 November 1944, AWM 54, 81/4/81.

detected.'[190] At that range the U-boats stood a good chance of slipping through the gaps in the escort groups asdic front, or even passing round the flank of their search.

The low asdic detection performance was due to the adverse effects of shallow water operations including bottom echoes and high reverberations, and because the U-boat's tended to bottom when near A/S vessels. Part of the problem was that the escorts failed to follow up aircraft sightings, even though some 30% were less than 30 miles, or 2 hours steaming from a support group. DNOR noted that the "bird in the hand" was systematically ignored, and had ships made even '...moderate use of aircraft sightings their total chances of contacting U-boats would have been more than doubled.'[191] Within a month these deficiencies were rectified and the proportion of kills rose to a level equivalent to that previously achieved by support groups in ocean waters. Now, ships made better use of aircraft sightings, and spent more time searching the datum, though DNOR thought that these investigations should last at least 24 hours. Trials were also in hand to explore the co-operation of escorts working with aircraft using air-dropped omni-directional sonobuoys. Although some USN squadrons were using sonobuoys by June 1944, after months of trials, only one British squadron had used the equipment on operations.[192] Thereafter, progress was made.

> Sonobuoys have enabled aircraft to track submerged U-boats in calm weather once they have been located, but this requires good drill and competent listeners and may be rendered much less reliable by the background noises of a breaking sea or tidal stream. As a rough guide an aircraft with eight sonobuoys should be able to hold contact for 60-90 minutes, and one with twelve sonobuoys for three hours.[193]

But, the technology was in its infancy and, for the British at least, unsupported classification evidence from sono-buoys was not considered conclusive evidence of the presence of a U-boat.

In August Captain R. Winn in the Operational Intelligence Centre (OIC) came to the judgement that

> The evolution of the Snort [i.e. schnorkel] U-boat will be found to have affected profoundly the balance of power between hunter and hunted.... The U-boat will be

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[190] 'Notes on Two U-boat Cruises in the English Channel,' DDIC, DAUD, DNOR, OIC/SI/1021, 24 July 1944, ADM 223/261.
[191] 'Detection of U-boats in the English Channel and Approaches (Rough analysis of the period D to D+10),' E.J. Williams and L. Solomon, Report No. 48/44, 19 June 1944, ADM 219/131.
[192] 'Report on Development in A/S Tactics in the United Kingdom, June 1944,' AWM 54, 81/4/81, p. 12.
[193] Captain C.D. Howard-Johnston, DAUD, and Captain N.A. Prichard, DASW, Ref: D.559 (Draft), 5 August 1945, ADM 1/17653.

> able to remain submerged for up to 10 days without presenting any target detectable by radar or visually except at short range.[194]

At the same time, Williams and Solomon drew together the available information from operations and special intelligence. The weather often precluded schnorkelling in seas greater than force 5, though as experience was gained some boats did better. By assuming that U-boats maintained a speed of 2 knots while fully submerged, DNOR were able to make a direct comparison between the schnorkel and non-schnorkel boats on passage:

	Schnorkel	Non-Schnorkel
Hours charging per day	5 hours at schnorkel depth	2 hours surfaced
Distance made good per day	50 miles	70 miles[195]

However, considering the lower battery usage when in an operational area, the average time schnorkelling was thought to be about 3 hours per day.[196] This helps to explain why, amongst Coastal Command crews, there was a '...growing frustration of failing to sight U-boats known to be in specific areas.'[197] Worse, over the months that followed many of the claimed sightings were actually incipient waterspouts, or "willywaws", misidentified as schnorkels because of the mistaken belief that the schnorkel emitted smoke. This may have been culled from a captured German document of April 1944, which could have come into NID's possession at this time, and described '...puffs of exhaust gas of Schnorchel....' The document suggested that measures were being taken to redesign the schnorkel head and other measures to reduce both this and the wake from the schnorkel.[198] From the number of contacts gained by aircraft, the amount of flying done, and the total time assumed to be spent by the U-boats schnorkelling, the analysts were able to estimate that the swept width achieved by Coastal Command's aircraft was less than 700 yards by day and 100 yards by night. Even taking account of errors in the data the swept width was unlikely to be more than a mile by day and fifth of that by night. This meant that if an aircraft was searching a 5 mile wide lane, then its effectiveness would be about 4%. By comparison the swept width for an aircraft searching for a surfaced U-boat was about 5

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194 'U-boat Situation, Week Ending 28 August 1944,' Captain Rodger Winn, RNVR, OIC/SI.1062, n.d., ADM 223/172.
195 'Note on the value of "Snort" to U-boats,' L. Solomon and E.J. Williams, DNOR, Report No. 62/44, 19 August 1944, ADM 219/144.
196 'Note on U-boats Fitted with Snort,' DDIC and LS/EJW, DNOR, OIC/SI.1036, 11 August 1944, ADM 223/172.
197 'The Schnorkel Smoke Myth,' Appendix V, in, 'The RAF in Maritime War, Vol. V...,' AIR 41/74, p. 1.
198 'Detection of Schnorkel Fitted U-Boats,' Headquarters, Coastal Command, CC/S.17261 A/U Ops., 17 December 1944, AWM 54, 81/4/81.

miles by day and 3-7 miles by night. Williams and Solomon concluded that when U-boats were able to charge their batteries by schnorkelling, they were nearly 8 times safer than if forced to the surface.[199]

Williams continued to assess A/S operations against the schnorkel-fitted U-boats. He deduced that the best opportunities for offensive action against U-boats operating inshore were in the shipping areas (and not just with convoys). Williams reasoned that the shipping areas were small, compared with the U-boats' extensive transit routes, and so it was there that the U-boat density would be highest, and thus the opportunities for action greater. Of course, A/S forces in the shipping area also had a direct deterrent effect on the U-boats' activities. The question then was, whether the escort groups should operate in the close vicinity of the convoys in direct support, or patrol in probability areas? The answer depended on the frequency of attacks by the U-boats. If attacks were infrequent, it was better for the escorts to search in probability areas, since the U-boats would only rarely be encountered around convoys. On the other hand, if attacks became more frequent, then

> ...the surface groups should be close to a convoy, since this would not only contribute to the direct defence of the convoy, but also offer the surface groups with frequent opportunities for attack.

Williams suggested alternatives for the stationing of the surface escort. He thought that the safety of the convoy

> ...would be temporarily best assured if the surface groups formed a screen ahead and on the flanks of the convoy, to maximise the chance of forcing the U-boat to bottom or of detecting the U-boat <u>before</u> attack. On the other hand opportunities for counter-attack would probably be greater if the surface group kept astern of the convoy and pounced on any attacking U-boat.[200]

When the escort was weak, ships should tow foxers to deter or confuse approaching U-boats, but, Williams reasoned, where the escort was strong the A/S ships should rely on zig-zagging for protection against Gnat attacks. The reduction of noise by not towing foxers would make it more likely that the escorts would gain contact on a U-boat. If this happened, or the U-boat betrayed itself by attacking, then surface forces were to concentrate on the area to produce a flooding effect. The search should then be maintained for at least 24 hours, particularly in shallow water where the U-boat could bottom. Other staff in the Admiralty considered that the search should be continued for at least 48 hours. It was also clear that there was not complete agreement over when

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[199] 'Note on the value of "Snort" to U-boats,' L. Solomon and E.J. Williams, DNOR, Report No. 62/44, 19 August 1944, ADM 219/144.
[200] 'A/S Operations against Snort U-boats Working Inshore,' E.J. Williams, DNOR, Report No. 66/44, 29 August 1944, ADM 219/148. [emphasis supplied]

escorts should tow foxers. From the discussion over the employment of aircraft, it is evident that the staff were still of the opinion that in rough weather the U-boats might be unable to schnorkel and eventually forced to surface. Williams, in particular, took a rather theoretical stance by suggesting that air resources should be husbanded for just this circumstance, when they might be used to greatest effect. The DASW staff, on the other hand, thought that air cover was best employed attempting to interrupt schnorkelling.[201]

British Tactical Countermeasures

When, in mid-1944, the schnorkel-fitted U-boats began operating in the Channel against the invasion forces this yielded poor results, and they soon transferred their attention to the North-West Approaches.[202] The British had anticipated such a move and were able to implement pre-formed plans when the move was detected by British intelligence. The plan called for support groups to be deployed in widespread patrols, known as Operation "CW" and later "CE", across threatened trade routes where they were at hand to reinforce convoys, (just as had been done with the hydrophone trawlers during the First World War as noted in Chapter 1). The A/S groups could also carry out offensive sweeps in their areas. This was an extension of the operations of support groups, which since the winter of 1943 had been used in the Atlantic on offensive sweeps 60 to 120 miles ahead of threatened convoys, as U-boats adopted less aggressive tactics of maximum submergence by day.[203] These tactics continued to be used in the Arctic, where "hunting" groups were sent out ahead of convoys to keep the U-boats down. In each case the greater reluctance of the U-boats to engage in convoy battles, meant that the A/S forces had to operate further afield, if encounters were to be forced and U-boats destroyed. The A/S operations in late 1944 were of a more static nature, matching the U-boat tactics. Perhaps three escort groups, with air support, would be assigned to an area roughly 100 miles square. The groups did not operate as a cohesive unit but patrolled the area as directed by their individual Senior Officers, responding to intelligence cues and aircraft sightings, reinforcing the close escort of convoys passing through the area.[204]

Directly supporting convoys accounted for about 20% of the support groups' time at sea, the remainder being spent patrolling their area. The object was: 'The safe

[201] Commander E.H. Mann (Ret), DASW, to DAUD, 6 September 1944, ADM 219/148.
[202] Those still without schnorkel were severely handled by A/S forces.
[203] 'Periodic Summary of the Anti-U-Boat Campaign, No. 37 – 4 December 1943,' Captain C.D. Howard-Johnston, DAUD, 6 December 1943, File D 01-18-0, Vol. 11575, RG 24, NAC, pp. 2-4.
[204] 'Standing Orders for U-boat Hunts off Northern Ireland (Short Title: Operation "CW"),' Commander-in-Chief, Western Approaches, 24 February 1944, ADM 199/468, p. 2.

passage of shipping through the focal areas.' But when no convoys were present, the object was '...the destruction of U-boats operating in these areas.'[205] DNOR calculated that the patrolling support groups would have passed within five miles of a U-boat at least once per day, even if the Groups had been disposed at random.[206] Since, they were actually deployed on the available intelligence, it was likely that U-boats would have been aware of a support group, perhaps two or three times a day. PoW confirmed that the U-boats had indeed been swept over frequently without contact being made by the A/S ships. Added to which, the U-boats would have been subjected to constant over-flights by Coastal Command aircraft. 'Consequently,' McCrea concluded, 'the U-boats lived under a constant threat of detection and it is small wonder that they were slow to take the initiative in attacking.' This assertion was borne out by PoW reports. 'The weakness of the situation from our point of view,' McCrea continued,

> ...was thoroughly appreciated. It required only one or two U-boats a little bolder than the rest to demonstrate to their fellows that, despite the strength of our patrols, they could attack with but little fear of retribution.[207]

The U-boats were inexpert in submerged, inshore operations, especially in the effective use of the schnorkel. To carry out attacks the enemy were expected to operate singly, and to bottom under a shipping lane, waiting for a convoy to approach. The U-boat would then rise and attack using periscope observation by day, or in bright moonlight. The enemy was also experimenting with attacks using hydrophone bearings to fire from deep into the brown of convoy's HE. This method could be used at night, but with existing equipment was not successful. Either a single homing torpedo, or a salvo of pattern-running torpedoes were fired at the convoy or the escort, often at long range and sometimes from astern.[208] The operational timidity of the U-boats had long been noted, and in September 1944 they were still not operating in an offensive manner, except for the occasional aggressive U-boat commander. They rarely gave the escort groups the opportunity to destroy them by attacking convoys. At first the escorts were also inexperienced in the subtleties of inshore operations and only exacted retribution on about one in eight of the U-boats which attacked. The difficult acoustic

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[205] 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501, p. 358.
[206] 'Operation "CW"...,' ADM 1/17653.
[207] 'Survey of A/U Operations in UK Coastal Waters, July 1944 – May 1945,' [W.H. McCrea], DNOR, 13 July 1945, ADM 1/17653, p. 4.
[208] 'Inshore U-Boat Operation,' Admiralty Message, CASO No. 6, DTG 252307A October 1944, NAA(M): MP1185/8, 1932/3/45.

conditions and the tendency of the U-boats to bottom when near A/S ships, reduced asdic performance to less than 20% of its normal efficiency.[209]

Classifying contacts on the bottom was especially difficult, as Commander J.D. Prentice, RCN, Senior Officer of EG11, discovered. Echoes from wrecks were often better than those obtained from a U-boat which were often woolly. There was no doppler and no wake echo both of which helped in classification in deep water. And in a strong tidal stream, trying to plot the movement of the target could be deceptive, and it was easy to shift target inadvertently from the initial contact to an adjacent non-sub, without the use of radar or radio aids (such as QH) to accurately fix the ship's position.[210] Although the numbers of U-boats destroyed was low, they still lost one U-boat for every two ships sunk in the convoys.[211] Thus there was a kind of stalemate, as Captain Howard-Johnston, DAUD, noted. The problem of dealing with the schnorkel-fitted U-boat was very different from the open ocean operations of 1941-43, in particular the U-boat was practically immune from location by aircraft.[212] However, with the imminent loss of the Biscay ports, the U-boats would find it very difficult to renew ocean operations against convoys that could be spread across a greater swath of water making them more difficult to find. It seemed certain that the U-boats would confine their operations to inshore waters, however, Howard-Johnston thought,

> ...the enemy will [not] gain any further marked advantage from his operations until the advent of the fast U-boat either inshore or in deep waters, when our future asdic successes may be seriously reduced by the enemy's power to evade the individual attack.[213]

Whether on patrol, or when searching for a U-boat that had betrayed its presence, escort groups had to laboriously attack every suspect contact to try to bring up evidence of a U-boat. The problem, as Commodore G.W.G. Simpson, Commodore (D), Western Approaches, himself a renowned submariner, noted, '...the disintegration of the hull cannot reasonably be expected however many charges are dropped on it.'[214] During attacks about four out of five brought up only oil or nothing at all – not enough to

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[209] 'Inshore Operations,' Appendix (ii), to, 'Type XXI U-boat (A Provisional Appreciation),' E.J. Williams, DOR/44/68, 4 September 1944, ADM 219/150.
[210] 'Submarine Warfare in the Channel,' Commander J.D. Prentice, RCN, Senior Officer EG11, HMCS *Ottawa*, to Commodore (D), Western Approaches, 17 July 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.
[211] See Appendix 4.
[212] 'Anti-U-boat Operations Inshore,' Captain C.D. Howard-Johnston, DAUD, Ref: D.218, 11 September 1944, ADM 223/20.
[213] 'Anti-U-Boat results inshore in Western Approaches Command for the period 1 September 1944 to 31 January 1945,' C.D. Howard-Johnston, DAUD, D.353, 4 February 1945, ADM 205/44.
[214] Minute, Commodore G.W.G. Simpson, RN, Commodore (D), Western Approaches, No.DW.40/603.OP, 26 July 1944, File D 01-18-0, Vol. 11575, RG 24, NAC.

differentiate between a U-boat and a wreck.[215] Moreover, attacking an indifferent asdic contact posed problems. A series of trials were carried out to determine in which direction the U-boat was lying, and several of the escort groups developed attack methods based on the use of the echo-sounder so that the ship could pass directly overhead of the U-boat and accurately place a small number of depth-charges on the target.[216] Escorts often persevered with these attacks against individual contacts continuously for up to 48 hours. 'It is most strongly emphasised,' Howard-Johnston remarked, 'that persistence in the search or hunt is of the greatest importance until clear evidence of destruction is obtained.'[217] Such persistence was equally vital in other operational areas, such as the Indian Ocean, where environmental conditions were very different. For example, Commander G.A.G. Ormsby, SO of EG60 in company with two CVEs of Force 66, hunted for *U-198* for a week before she was sunk in August 1944.[218] Some months later, Lieutenant Commander J.P. Mosse in command of HMS *Mermaid*, was instrumental in the destruction of two U-boats in the Arctic after long hunts. The convoy escorts were arranged in depth, with *Mermaid* and others forming advanced striking forces. They carried out a '...a vigorous defensive [that] resulted in hard blows being struck at the enemy.'[219]

Maintaining this level of aggressive searching was not easy for tired escort group commanders.[220] It was in any case very time consuming, and some escort commanders sought for methods to catch an attacking U-boat before she managed to reach the bottom. Commander P.W. Burnett, one of the best U-boat killers and now Senior Officer of the EG10, for example, complained about the difficulty of getting contact on a bottomed U-boat.[221] There were days, he wrote 'when one gets no echoes from a known wreck....' He reasoned that '...there must be about 20 minutes when a U-boat attacking a convoy is clear of the bottom and not manoeuvring to avoid

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[215] 'Choice of Weapons for "Opening-Up" U-boats,' Section V, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB.
[216] 'U-Boat Tactics,' Secretary, Navy Board, Melbourne, 22 September 1944, NAA(M): MP1185/8, 1932/3/45.
[217] 'Experience Gained during Anti-U-boat Inshore Operations,' Captain C.D. Howard-Johnston, DAUD, Ref: D.218, 11 September 1944, ADM 223/20, p. 2. [emphasis supplied]
[218] 'A Model Anti-U-Boat Operation in the Indian Ocean – 5-14 August 1944,' Section 6, 'Monthly Anti-Submarine Report, July 1944,' DAUD, CB04050/44(7), 15 August 1944, NHB; 'Abstract 24, AHH,' TSD/Historical Section, Abstract Volume 24, A.H. Haggard, n.d., NHB.
[219] 'Operation "Victual" Passage of Convoys JW59 and RA59A to and from North Russia,' Captain C.D. Howard-Johnston, DAUD, 15 November 1944, ADM 199/351.
[220] Michael Whitby, 'The Strain on the Bridge,' in, John Reeve and David Stevens (eds.), *The Face of Naval Battle: The Human Experience of Modern War at Sea* (Crows Nest, NSW, Australia: Allen & Unwin, 2003), pp. 200-218.
[221] Gretton to Howard-Johnston, 15 September 1980, 'H-J' File, Gretton Papers, MSS/93/008, NMM(G).

detection.' By stationing his support group in a dense screen ahead and astern (and even inside) of the convoy, his idea was '...to have an escort within Asdic range of him when he fires.' This, Burnett thought, was '...much more important than a tidy organized sweep which gets there half an hour later when he is back on the bottom.'[222]

Here, indeed was a conundrum. The key was to get as many as possible of the escorts within asdic range of the U-boat. Speed, as Burnett and others highlighted, was crucial. But so was an organized search, which ensured that as much of the U-boat probability area was covered as possible. When this was not achieved the U-boat would often escape. Burnett commented in early 1945, that

> In coastal waters if one obtains no contacts it may be concluded that detection conditions are bad, and a bottomed U-boat is likely to be swept over undetected. If conditions are good, on the other hand, thorough investigation of all contacts delays a search so long that a reported U-boat has a good chance of escaping.[223]

The Admiralty promulgated a search plan called Operation "Scabbard" designed to locate a U-boat which had retreated to the bottom after attacking a convoy {*Plate 16*}. The most probable area where the U-boat was likely to be was within an annulus 2,500 yards to 4,000 yards around the torpedoed vessel. It was assumed that the U-boat would lie on the bottom head to tide. One escort was to close the position of the torpedoed ship to obtain information from survivors and establish the datum. Meantime, all other available escorts were to immediately form up 5,000 yards from wreck and search across the U-boat probability area, sweeping across the tide so that the ships would, hopefully, approach the bottomed U-boat on its beam, where its asdic echo was most pronounced. The search was then repeated in the opposite direction. After that the ships reverted to a square search around the perimeter of the "Scabbard" area. The plan, though not formally included in the tactical manual until the end of 1945, was soon being practiced by escort groups in their continuation training between convoy operations.[224]

Operation "Artichoke" was another organized plan designed to search for a U-boat which had attacked a convoy in daylight (or bright moonlight) and was either still under the convoy, or had escaped on the quarters or astern of the convoy. The escorts in the van turned onto a reciprocal course to the convoy and search back through the

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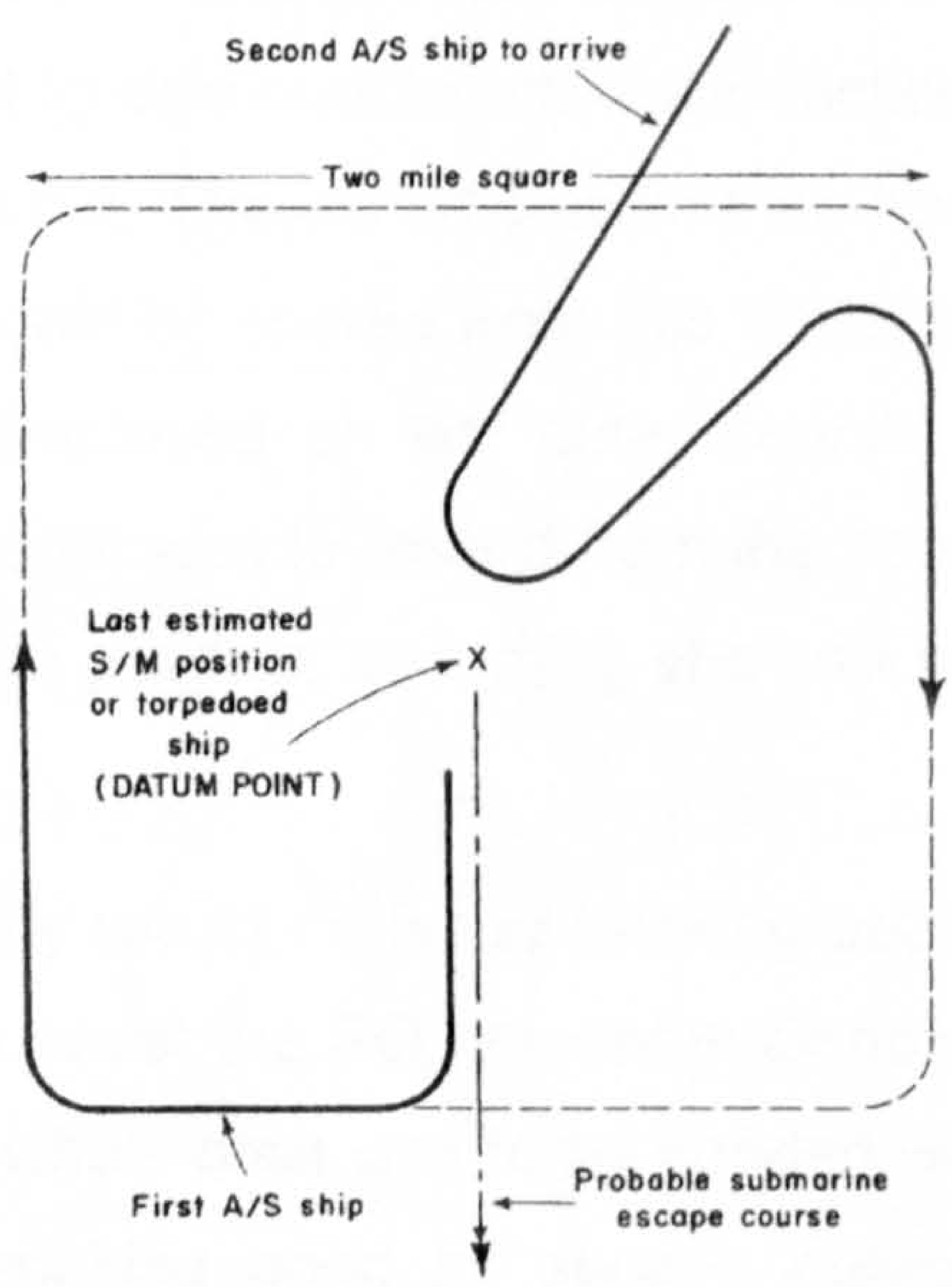
222 Commander P.W. Burnett to Captain C.D. Howard-Johnston, 12 November 1944, ADM 199/501. Burnett was referring to the operations of his Escort Group in mid-September 1944.
223 'Report of Proceedings, Tenth Escort Group, 26 December 1944 to 3 January 1945,' Commander P.W. Burnett, RN, No. 1A/8, 4 January 1945, ADM 217/373.
224 Admiralty Message to AIG #2 359AZ, Repeated to Commander 12th Fleet, 26 August 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

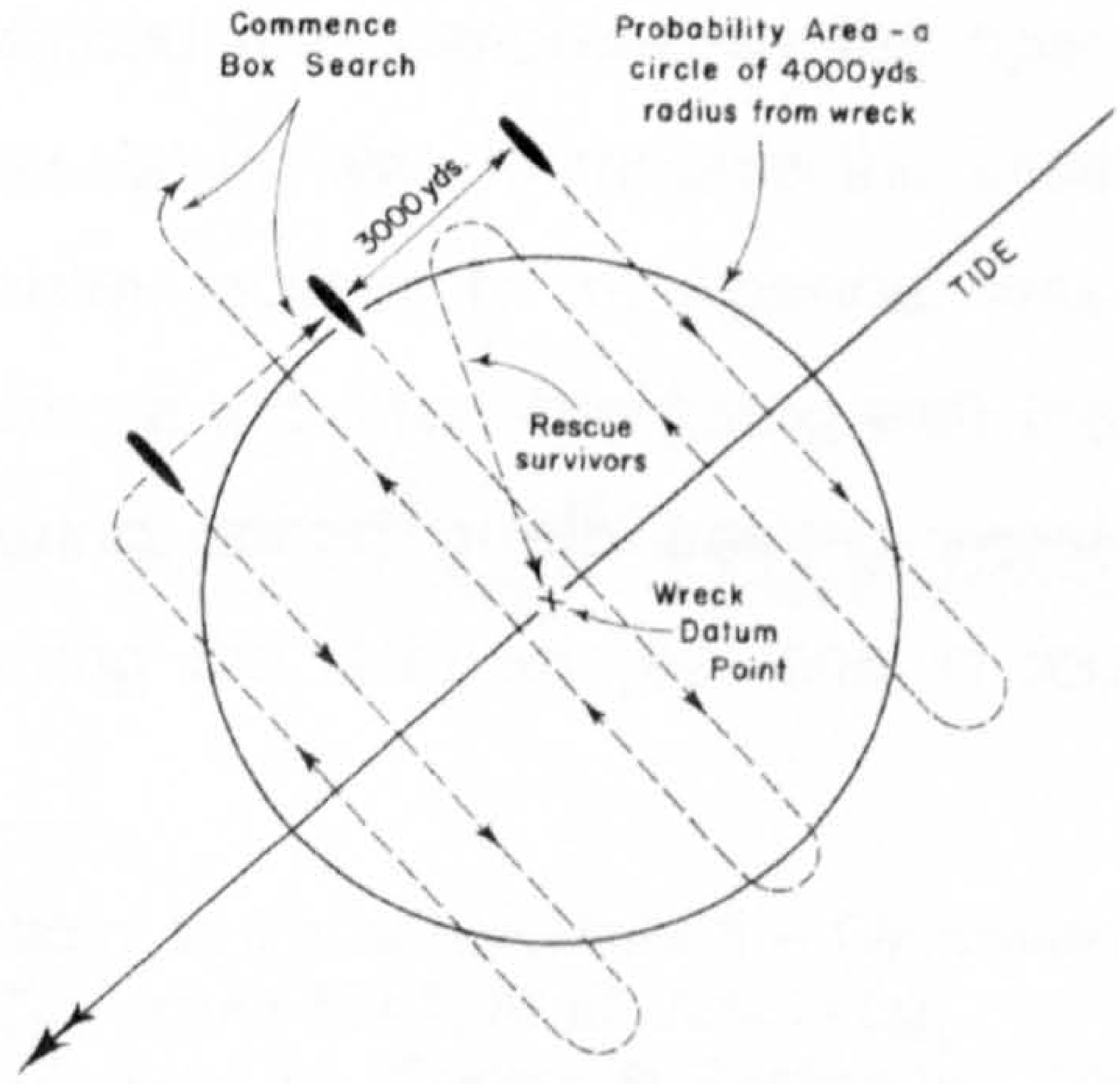
Plate 16: "Observant" and "Scabbard" Search

'Summary of U-Boat Searches (SUBS), 1945,' CBCN. 7402, NSHQ 75-599/500, n.d., Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 345, RG 38, National Archives and Records Administration 2, College Park, Maryland, pp. 25 and 45.

SQUARE SEARCH
"OBSERVANT"



SCABBARD SEARCH



convoy columns until they came abreast of the rear escorts, these, too, would turn and join in the search until the ships were 6,000 yards astern of the convoy. All ships would then about-turn and sweep back towards the rear of the convoy. Only the escort vessel in position "S" directly astern of the convoy acted differently. She was to close the wreck, taking anti-Gnat precautions, and try to determine on which side that ship had been torpedoed (not easy if the ship had been hit by a Gnat or LuT torpedo), before carrying out an "Observant" around the position of the torpedoing {Plate 16}. If "Artichoke" failed, the support group could continuously cover the 6-mile square centred about the position of the torpedoing for at least 48 hours, depth-charging every likely contact in the area. Even if these tactics failed to find the U-boat, it was assumed they would force the U-boat to continue its anti-asdic tactics until finally forced to move when the air in the boat ran out. The escort's asdic then had a chance of detecting it. If there were escorts which could be spared from this "inner search", or if reinforcements arrived, they were to be employed on an "outer search" as directed by the Senior Officer on the spot. This search was to extend from the boundary of the inner search to the U-boat's likely furthest-on position, assuming she was tying to escape at a speed of 2½ knots.[225]

The operating authority would, '...issue tracking appreciations of the most likely movement of the U-boat to assist the SO present in disposing his patrols on the Outer Search.'[226] In addition, the whole area was to be flooded with aircraft to prevent the U-boat from surfacing and making good its escape outside radar range of the A/S vessels. Any possible Schnorkel sightings by the aircraft were to be followed up immediately. The SO was able to establish new datums based on these sightings if he considered they warranted it and to detach ships from the outer searching force to carry out investigations along the lines of the original inner search. This inner search, however, was to be maintained until cancelled by the operating authority who would also decide whether a new datum was to replace the initial one. This control by the shore authority, with its better access to intelligence, was a feature of the inshore campaign, but occurred without too often interfering with the SO's tactical initiative, so assiduously developed during escort group training sessions.[227] And the intensive training had its effect. During the later stages, one in four of the U-boats' attacks

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[225] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(44)(2), August 1944, NHB, Article 56.
[226] 'DAUD 081734B to C-in-C, WA,' in, 'Friday, 8 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.
[227] 'C-in-C, WA, 092035 to Admiralty,' in, 'Saturday, 9 September 1944, War Diary (Naval), 1-14 September 1944,' NHB; 'Monthly Anti-Submarine Report, October 1944,' DAUD, CB04050/44(10), 15 November 1944, NHB.

resulted in their own destruction. But the big increase in U-boat sinkings was not in those associated with torpedoings. Ships and aircraft on patrol also began to take a heavy toll. This suggested to McCrea, who had no access to special intelligence, that the improved results had more to do with increased experience amongst the A/S forces and not merely to the changes in dispositions. Thus, when the U-boats made their final spurt, their days of comparative immunity had vanished. Nor was the risk to the escorts minimal. Professor W.H. McCrea, DNOR concluded that on average 40 escort vessels had been at sea with the support groups between July 1944 and March 1945. These ships had destroyed 37 U-boats, but the U-boats had, in return sunk 10 of the anti-submarine escorts.[228] Nevertheless, the tactical use of anti-Gnat material countermeasures, Howard-Johnston realized, 'must be left to the Commanding Officer's discretion.'[229]

These searches were used principally in the vicinity of convoys after an attack had occurred. The detailed convoy instructions for the conduct of the close escort and support groups, were contained in Horton's Operation "Gooseberry", which was '...designed to cover the probable actions by a U-boat Commander when operating in an area where his evasive measures may include bottoming.' To meet this kind of attack by a U-boat, the success of counter-measures would depend largely

> ...on escorts reaching the scene without delay. Broadly speaking, the plan allows for close escorts in positions astern of the convoy to search for the U-boat should he bottom in the immediate vicinity; an inner patrol to contain him to the limits of exhaustion, and an outer patrol to catch him should he by chance have evaded the net thrown round him.[230]

The dispositions furthest from the convoy were made up of air patrols, designed to force the U-boat to approach submerged and, if there were enough aircraft available, to have some chance of detecting an unwary U-boat using schnorkel or periscope. The air escort for convoys in the focal areas was normally to consist of four box patrols parallel to the convoy track, and moving to keep pace with the convoy's progress. The path ahead of the convoy that would be swept was to a distance of 28 miles either side of its mean line of advance out to approximately 60 miles ahead of the convoy. A close air escort was sometimes provided in addition to the box patrols, which, in the absence of other instruction from the Senior Officer of the Escort, was to carry out a continuous

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228 'Survey of A/U Operations...,' ADM 1/17653.

229 'Experience Gained during Anti-U-boat Inshore Operations,' Captain C.D. Howard-Johnston, DAUD, Ref: D.218, 11 September 1944, ADM 223/20, p. 4.

230 'On a Ship in Convoy being Torpedoed in an Area where the U-boat can Bottom,' Appendix IV (7 April 1945) to, 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501, pp. 371-374.

patrol round the convoy at a distance of 5 miles, where it might be able to detect a U-boat using its periscope as it worked itself in a firing position on the convoy.[231]

The planned dispositions of the surface escort around, and supporting, a convoy were designed to maximise the chance of locating and destroying an attacking U-boat. Thus, for an ocean convoy formed on a broad front and approaching one of the focal areas, the close escort was to be stationed in accordance with Admiralty Convoy Instructions, if no support group was available. At the time this close escort was expected to consist of between five and eight escorts. These would be disposed roughly equidistant around the convoy with the emphasis on ships stationed on the wings and astern of the convoy.[232] If a support group was present by day the best way of disposing it was, firstly, to augment the close escort so that an A/S screen could be formed, with the support group ships normally occupying the wing positions. This screen, with ships spaced [3,000] yards apart was designed to catch a U-boat which had risen from the bottom on hearing the approaching convoys, and was now manoeuvring into an attack position. With this screen ahead formed, any spare escorts were to be stationed astern and on the quarters of the convoys to act as "pouncers", able to rapidly react to a torpedoing. By night, except in bright moonlight, it was unlikely that a U-boat would be manoeuvring to make a torpedo attack from periscope depth. The priorities for stationing the support group were therefore reversed. Its ships were, firstly, to fill the "pouncer" positions, where they might catch a U-boat which had fired a long-range "browning" shot, possibly from astern of the convoy. Any spare ships of the support group were to augment the close escort on the forward screen, preferably taking the wing positions. Once the convoy entered the cleared channels through the defensive minefields it would reform with a narrow front (thus resembling a long column). The close escort was then to be evenly disposed round the convoy, with the support group disposed on both sides, and nearer the rear than the front of the convoy. Horton emphasized that if a U-boat was detected by the screen or revealed its presence by attacking the greatest chance of killing

> ...is whilst the scent is fresh. Any delay in closing the datum point reduces the chance of a kill. The situation calls for the utmost rapidity of decision, combined

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[231] 'Air Operations,' in Appendix VII to, 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501, pp. 377-379.

[232] 'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(44)(2), August 1944, NHB, Articles 34 and 35.

> with speed and clarity of communications, as well as the efficiency of weapons, instruments and their operators.[233]

When such an attack took place, A/S forces were to carry out an asdic sweep of the immediate area surrounding suspected position of the U-boat. Numbers of escorts permitting, this was best achieved if at least two A/S ships were stationed close astern of the convoy to act as pouncers. Of course, these neat "textbook" tactics were more difficult to carry out in practice. Even in daylight when the ship torpedoed could be seen and the side of the attack ascertained, it was not easy to identify the correct position of the datum. The result, said Lieutenant Commander Raymond Hart, Senior Officer EG21, in early February 1945 was that a hunt commenced '...along the lines of "Gooseberry".' The many non-subs in the coastal waters prolonged the search, but supported by EG5, Hart's persistence, probably resulted in the destruction of one U-boat and heavy damage to another.[234]

Tactics Refined from Experience

By February 1945 the Admiralty had refined its advice of the previous autumn on convoy protection in Inshore waters for the Escort Groups. They once more pointed out that on ocean routes the U-boats normally had had considerable distances to cover if they were to reach favourable attacking positions. Allied air cover and distant screens of A/S ships were able to prevent U-boats moving freely on the surface. However, the introduction of the schnorkel by the Germans required considerable changes in the employment of anti-submarine forces for convoy protection. In coastal waters U-boats were able to operate in areas where shipping was easy to locate on the well established convoy routes. As a consequence the U-boats did not have to move over large distances, and with the adoption of continuous submerged operations (made possible by the use of the schnorkel), Allied air patrols and distant screens of A/S ships were rendered largely incapable of detecting any U-boats lurking in the path of a convoy. By the early spring of 1945 the U-boats were becoming more adept in exploiting the difficult environmental conditions and the A/S forces limitations. They surfaced very rarely in areas of heavy air reconnaissance and normally charged their batteries by schnorkelling at night in quiet areas. Attacks were generally made from periscope depth during the day or by moonlight. McCrea's estimate of the effectiveness

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[233] 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501, pp. 359-360.

[234] 'HMS *Conn*, Report of Proceedings, 11 January to 2 February 1945,' Lieutenant Commander Raymond Hart, DSC, RN, Senior Officer 21st Escort Group, 5 February 1945, ADM 217/755; '5th Escort Group Narrative: 21 January – 12 March 1945,' NHB.

of escorts in detecting U-boats in inshore waters was rather pessimistic. The data suggested that the escorts had only about an 8% chance of detecting a U-boat as it approached to attack a convoy.[235] There was little new in this discovery. A/S practitioners, like Howard-Johnston and Burnett, would have remembered the results of tactical screening exercises in the late 1920s which had shown that at least 45% of submarines passed through a screen without being detected. And this in exercise conditions, with the operators fully alert to the presence of a submarine.

Accepting the low probability of detection, British tactical countermeasures nevertheless were based on the policy of providing maximum asdic protection and immediate counter-attack after a U-boat had attacked. Protection was afforded by deploying a strong asdic screen two miles ahead when a convoy in ocean waters was formed on a broad front. For coastal convoys the escort was to be maintained both ahead and alongside the flanks when convoy was formed on a narrow front. This concept was not new. Earlier tactical instructions had suggested the use of a closely spaced, line abreast escort screen ahead of the convoy when it was assessed that submerged U-boats were lying in wait ahead of the convoy. If a support group was available it was deployed to reinforce the close escort by extending the screen ahead of the convoy. Meanwhile, at least one escort was stationed within a mile of the rear of the convoy to act as a "pouncer", which was well placed to close the wreck and start the search in the likely area where the attacking U-boat could be, while the scent remained strong. When a support group was present at least one ship was to be used to reinforce the "pouncer". If a second support group was available, the whole Group was to be deployed astern of the convoy to act as a powerful "pouncer" force to exact retribution on a U-boat that had attacked. The key was to start the search without delay and before the U-boat could have moved far away, or ensconced itself on the bottom. The A/S tactics recommended were designed, firstly, to rapidly concentrate practically the whole of the escort, including any support groups, in the likely area where the enemy could be, and secondly, to seal off that area while the search continued until destruction of the U-boat was achieved. Minimal protection of the convoy was accepted (because these schnorkel-fitted U-boats were operating singly, rather than in packs, so another U-boat was unlikely to be found close-by).

As soon as a ship in the convoy was torpedoed, one, or ideally two, "pouncers" were to close the wreck from the rear of convoy and carry out a standard Operation "Observant", with sides two miles long. Remaining escorts initially stationed in the rear

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[235] 'Survey of A/U Operations…,' ADM 1/17653, p. 7.

of the convoy were to establish a "Square" Search outside the "Observant". The size of the "Square" Search was recommended to be a six-mile sides, unless in the prevailing circumstances the Senior Officer present decided on a different size. Meanwhile, the ships in the van were to contribute to the asdic search most effectively by executing an Operation "Artichoke", during which the escorts would sweep back through the columns of the convoy. Once clear of the rear of the convoy, these ships were to take up positions on the "Square" Search, with any ship left over after filling the "Square" Search used outside it to search on the U-boats most probable escape course. Once these immediate countermeasures were in place, at least one ship of the close escort should be detached to rejoin the convoy. When one or more support groups were with the convoy, the whole convoy close escort was to re-establish the forward screen after Operation "Artichoke".[236]

The action recommended on completion of the immediate searches appeared in an amendment to the "Atlantic Convoy Instructions", issued in April 1945.[237] If the "Observant" and "Square" searches did not yield a contact, the force was to carry out two sweeps through the area at right angles to the tide and with the ships in line abreast and spaced 3,000 yards apart. Subsequent searches, it was suggested, might be carried out down tide of the original datum.[238] Recent experience of inshore operations indicated that after U-boats had attacked and especially when escorts were close by, they would immediately bottom or drift with the tide. Any movement by the U-boat was likely to be at silent speed of 3 knots or less, though the enemy might accept the risk of using higher speed if the U-boat could make enough ground to outflank a searching force, or to make a withdrawal up wind. To make it more difficult for the U-boat to get round the flank of an approaching search force, the searching ships should be stationed 2 miles apart and they should carry out a wide 30º-50º zig-zag to broaden the search front even further, accepting that the speed of progress would be diminished. The U-boat would therefore be faced with a difficult and changing problem.

Professor McCrea's analysis of Operation "CW" supported this policy. He deduced that to make the search as difficult as possible for the U-boat to evade, the ships should be widely spaced and should carry out a broad zig-zag. The alternative of a narrower front and a less drastic zig-zag would '...invite the U-boat to attempt to

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[236] 'Convoy Protection in Inshore Waters,' Admiralty Message, CASO No. 7, DTG 131737Z February 1945, NAA(M): MP1185/8, 1932/3/45.
[237] 'Inshore Operations,' in, 'Admiralty Convoy Instructions to Escorts (Short Title ACI), General Sections 1-6,' Part XII, DAUD, CB04234(44), April 1945, ADM 239/345.
[238] 'Admiralty Convoy Instructions to Escorts (Short Title ACI), 1944,' Part XII, 'Inshore Operations,' Anti U-Boat Division, August 1944, ADM 239/345, Article 163.

evade the group as a whole.' Although wide spacing might tempt the U-boat to try to pick his way between the ships, the broad zig-zag would tend to confuse his assessments of the positions of the "holes" in the escort line.[239] Where no direction could be decided, the area to be searched would be bounded by an expanding "furthest-on circle". The size of this circle would be dictated by the time elapsed since the U-boat attack. The recommended figures were: three miles for the first half hour; ten miles for the first two hours; and three miles for every subsequent hour.[240] When the new, faster Type XXI U-boats appeared, the Admiralty warned, the enemy might attempt to make more positive attempts to escape at higher speed, but in doing so they would have to accept the risk of exposing their HE to detection by the escorts. But the higher speed and longer endurance of these U-boats meant the area to be searched by the escort forces would expand much more rapidly, than in the case of a conventional, schnorkel-fitted U-boat. In February 1945, however, there was no indication that Type XXI U-boats were ready for operations.

Coastal Command's Response

Coastal Command had also been devising new search tactics against the schnorkel-fitted U-boats. These were briefed and discussed at the bi-annual Squadron Commanders' Meeting held at Coastal Command Headquarters at the end of November 1944. At the meeting Captain Peyton-Ward, the Senior Naval Staff Officer at Coastal Command, observed that since the last meeting in March of that year the U-boats had completely revised their operational stance. Those which were not fitted with the schnorkel were unable to operate effectively because of the growing power and ubiquity of Allied air patrols. These boats were, therefore, forced to spend the majority of their time submerged where they were unable to re-charge their batteries and could make little progress on passage. Only with the introduction of the schnorkel, could U-boats survive under the intense air cover.[241]

Trials had recently been conducted by Coastal Command on aircraft detection capability against the schnorkel. When there was no sea clutter, radar could detect a snort at 4-8 miles. However, at night operational experience showed that when aircraft passed within four miles of a snort they had about a one in 50 chance of achieving a detection followed by a sighting with illumination. Sea returns probably played a major

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[239] 'Operation "CW": Analysis for NW Approaches, 25 August – 17 October 1944,' W.H. McCrea, DNOR, 1 December 1944, ADM 1/17653, p. 16.
[240] 'Air and Surface A/S Searches and Striking Forces,' Part 4, BR1679(4) [formerly CB4097(4)(44)], June 1944, NHB, pp. 14-15.
[241] 'Minutes of Squadron Commanders' Conference held at Headquarters, Costal Command on 29 November 1944,' AWM 54, 81/4/81, p. 2.

part in this poor performance, as did homing failures, and the snort diving on detecting the radar or illumination. Further trials were needed to identify the factors which contributed to success or failure.[242] At the November meeting Air Vice Marshal A.B. Ellwood, CB, DSC, Coastal Command's Senior Air Staff Officer (SASO), explained that the introduction of the schnorkel had made

> ...the U-boat so difficult to detect that...[the Command] had partially to abandon the offensive in the Northern Transit Area, and allocate the forces to the protection of our convoys. For the schnorkel enable the U-boats to slip through the transit areas almost undetected, and will similarly enable them to get to their operating areas without too much interference from the air.

Coastal Command's first call, Ellwood went on, was the protection of threatened convoys. This now meant that '...we are not able to be, as we should like, completely offensive in our policy.' The Command had, '...in fact been driven on the defensive to a certain extent.' To overcome this problem it was proposed

> ...to adopt an offensive method to apply a defensive policy. The future method of looking after convoys will not be by putting on a single aircraft at a time, but will consist in flooding an area ahead of the convoy in the same way and to the same frequency of cover as we flooded areas through which the U-boats had to pass during "Overlord".

These patrols were '...designed to sweep out an area along the path of the convoy in force to prevent the...[U-boats] getting at the convoys.'[243] It was expected that, once the Germans were comfortable with the operation of the schnorkel-fitted U-boats, they would start another major offensive in the near future, making use of the tactical advantage bestowed by the schnorkel. Since the enemy had not yet reached this stage, Ellwood stated that Coastal Command was taking advantage of the lull in U-boat activity to concentrate on squadron training before the battle re-started. The training would be focussed on the new tactics of "flooding" sweeps ahead of the convoys. Group Captain Taylor explained these tactics to the Meeting. He began by referring to SASO's explanation of the factors which had led the Command to adopt an offensive-defensive policy. The tactics to be adopted consisted of "offensive" patrols concentrated into a relatively small area ahead of each convoy. Each patrol would be designed so that an aircraft would pass over each part of the patrol area every half an hour. This, it was hoped, would ensure the detection of any U-boat which attempted to intercept the convoy. These patrols were in the form of four parallel boxes, each containing two aircraft and flown to keep pace with, and ahead of the convoy. Assuming that the radar detection range on a schnorkel was 3½ miles, this allowed the

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[242] 'Anti-Snort Trials,' E.J. Williams, DNOR, Report No. 70/44, 5 October 1944, ADM 219/152.
[243] 'Minutes of Squadron Commanders' Conference held at Headquarters, Costal Command on 29 November 1944,' AWM 54, 81/4/81, p. 3.

total area swept each side of the convoy's track to be 28 miles. The total width of the patrol area ahead of the convoy would therefore be 56 miles.

The patrol would normally be flown to a distance of about 60 miles, though the performance of each type of aircraft would dictate the precise range. So that the spacing of the two aircraft assigned to each box was maintained, the intention was that, whatever the aircraft type, each should spend exactly one hour on each circuit of the box. Clearly, the faster types of aircraft would have to fly further ahead of the convoy than the slower. To maintain the accuracy of the patrols, each aircraft was to check its position relative to the convoy by taking a radar bearing and range, before setting out on the next circuit. This was, Group Captain Taylor pointed out, '...a new departure in navigation technique, and no part of the standard drill.' Curiously, Taylor announced that this relative navigation technique would reduce the need for '...the numbers of winds found, drifts, and positions fixed by other means would be tolerated while the aircraft remained with the convoy....'[244] How accurate aircraft positioning during the rest of the patrol was to be maintained, without accurate wind-finding, was not explained, though there was some concentration on transit navigation.

Results of the Anti-Schnorkel Campaign

According to a DNOR report, less than 20% of the schnorkel-fitted U-boats were destroyed at sea by air attack.[245] However, ubiquitous Allied air patrols compelled the enemy to remain submerged, and rely on their schnorkel, which restricted their tactical mobility. Airpower also put the U-boats under constant fear of detection. The log for *U-247*, for example, contains almost daily reference to sightings of Allied aircraft. There was the possibility that the aircraft would home A/S vessels onto the U-boat's position.[246] An escort group summoned by an aircraft had a good chance of relocating the U-boat, but success relied on speedy communications and accurate navigation. These factors also highlighted one major difference between the ocean and inshore operations. Howard-Johnston noted that

> In the former, any action by the operational authority is unlikely to be of immediate assistance due to the distances reinforcements must travel. In the latter, air or surface reinforcements can usually be sent in a very short time and intelligence is likely to be more detailed and accurate.[247]

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[244] 'Minutes of Squadron Commanders' Conference held at Headquarters, Costal Command on 29 November 1944,' AWM 54, 81/4/81, p. 7.
[245] 'Survey of A/U Operations...,' ADM 1/17653.
[246] '*Kriegstagebuch*, *U-247*, 18 May to 28 July 1944,' NID, PG/30225/NID, FDS, NHB.
[247] 'Monthly Anti-Submarine Report, October 1944,' DAUD, CB04050/44(10), 15 November 1944, NHB, pp. 7-8.

Howard-Johnston's allusion to more detailed and accurate intelligence was, of course, based on the Admiralty and Command's access to high-grade special intelligence. The U-boats rarely transmitted at sea, though when they did it often led to intensive air and sea searches and the destruction of the boat.[248] What was more valuable was the decryption of messages from U-boat Commands to their U-boats, giving approximate details of routes and operational areas. Although more research is needed to understand this aspect, it is clear that the British shore authorities were making great use of this source to deploy escort groups and air patrols in areas where U-boat activity was likely to be greatest.[249] Support groups could therefore be deployed into relatively small patrol areas, where they could search for U-boats and reinforce transiting convoys most easily. Greater numbers of support groups were formed from the faster escorts released from ocean groups, once the convoy cycle was amended and the size of convoys substantially reduced in late 1944, the retention of escorts originally destined for the Far East as well as appealing to Canada for the transfer of even more support groups to British waters. A similar reorganization of shore-based aircraft (both Coastal Command and FAA) was undertaken, though in the sort of operations envisaged CVEs were of less value.[250] Command boundaries were also amended to provide more cohesive direction of the operations centred on Horton's Western Approaches Command.[251] These measures were made more effective by another significant difference between the ocean and inshore campaigns. This was the adoption by the U-boats of static tactics in place of the mobile tactics which had been a feature of ocean operations. This might be temporary, for when the new high-speed U-boats under development became operational, the enemy could return to more mobile tactics, albeit operating submerged.[252]

McCrea's analysis of the employment of the Support Groups showed that about 20% of their time at sea was spent supporting convoys. Since the patrol areas were close to the bases, most of the remaining 80% of the time was spent on A/S patrol. All told there were about 50 escorts in the support groups in November and December 1944. This figure rose to about 60 during 1945. These ships were responsible for

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[248] See, for example: '25 June 1944,' in, 'Translation of PG/30349, BdU's War Log, 16-30 June 1944,' FDS, NHB.
[249] See, for example, the series of papers in ADM 223/20, ADM 223/172, ADM 223/198, ADM 223/203, DEFE 3/732, DEFE 3/735 and HW 1/3191.
[250] 'C-in-C, WA 031805B to Admiralty,' in, 'Sunday, 3 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.
[251] 'Admiralty, 021511B to C-in-C, WA...,' in, 'Saturday, 2 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.
[252] 'Inshore U-Boat Operation,' Admiralty Message, CASO No. 6, DTG 252307A October 1944, NAA(M): MP1185/8, 1932/3/45.

sinking most of the 37 U-boats destroyed, which equated to about 1 U-boat per ship-year spent on operations. McCrea compared this to the results of a Canadian study which concluded that RCN ships had sunk 1 U-boat per 19 ship-years. 'This comparison,' McCrea asserted, 'has nothing to do with efficiency.' He quoted it

> ...merely to contrast two sets of experiences and to indicate that the operations in coastal waters did provide any individual ship with an exceptionally favourable chance of destroying a U-boat.[253]

McCrea's analysis showed that very nearly 50% of the U-boats were sunk by patrolling support groups. Why such a high proportion should have fallen to support groups on apparently "random" patrols is unexplained, but may be due to searches actually being focussed by special intelligence assessments. The support groups (which did most of the killing) spent only 20% of their time with the convoys, but it was during these periods that almost 30% of the U-boats were sunk, just over half of them after a ship in the convoy had been torpedoed. This was, McCrea noted, confirmation of the obvious fact that a ship had the best chance of avenging an attack if it is already present at the scene. The number of U-boats killed before they were able to attack was roughly proportionate to the time spent by the support groups with the convoys. McCrea also noted that the aggressive tactics of the support groups in attacking Gnat-armed U-boats led to one escort being torpedoed in each of the ten months of the campaign.[254] To minimize the danger it was important that at least two escorts should engage a U-boat. The pair also had a greater chance of holding contact and avoiding the confusion caused by non-subs, especially if they made use of their A/S plots and accurate fixing aids, like QH.

Amidst the non-sub infested inshore waters two chief lessons Howard-Johnston and Prichard highlighted in relation to searches were:–

> (a) that it is better to search meticulously a comparatively modest furthest-on area (e.g., speed of U-boat two to three knots) than to dissipate the effort by allowing for an improbably high speed of retirement; and
>
> (b) that a concerted search dependent on accurate station-keeping soon becomes disorganised as each ship in turn attaches herself to a doubtful asdic contact.

They also perceived that:–

> When there are insufficient A/S vessels to cover even a modest furthest-on area, it is advisable to endeavour to forecast the U-boat's most probable movements and commit the forces available to the best appreciation that can be made. Such tactics

[253] 'Survey of A/U Operations...,' ADM 1/17653, p. 6.
[254] See Appendix 4.

> should, however, be limited to cases of necessity, and the temptation to "plunge on a guess" should be resisted whenever a systematic search is possible.[255]

Strictly, as Professor McCrea earlier pointed out, a "random" search was just as likely to gain contact as "systematic" searches, such as "Gamma", "Vignot", "Observant", etc. McCrea also noted that a systematic search might be easier for a U-boat to avoid. Theoretically, this was possible but it relied on the U-boat being able to determine from its sensors where the escorts were and what they were doing. This was far from easy. The great advantage of a systematic search, McCrea acknowledged, and as Howard-Johnston and Prichard realized, was '...that it can quickly and easily be put into operation.'[256] Not all escort groups got it right.[257] Furthermore, even with faultless tactics it seemed that more U-boats had been missed by poor classification than by searching in the wrong place.

The Allies were faced with what seemed to be the dawn of a revolutionary "new" U-boat war ushered in by the schnorkel-fitted U-boat. However, this threat bore many similarities to those encountered during the First World War and the submarine tactics practiced in the inter-war period. That the gloomy forecasts of the outcome of the campaign were not matched by the actual results was, in part, because the enemy's tactics were quickly understood, but was also in large measure due to the British and Canadian crews of anti-submarine aircraft and ships. Their training had imbued them with confidence, initiative and a flexibility capable of coping with the new tactical situation brought about by the new German technology. The British were able to rapidly institute rigorous training for aircrews and escort groups. This was vital, since early on in the campaign:

> The standard of operational efficiency responsible for the defeat of the U-boat in the Atlantic, is now lacking due to absence of training in the last three months [during operations in support of "Overlord"]. This will be particularly applicable to new groups about to be formed. It is therefore essential that a proper group training cycle be instituted at once for all A/S forces operating in the focal areas.[258]

Two of the aspects in which training was shown to be necessary were:–

> (a) Senior and Commanding Officers needed to practice to realise the differences between asdic and radar screens or searches; the effects on the U-boats movements of the possibility of bottoming and the concentration of traffic; and the difficulties of thorough search in an area where non-subs are prevalent.

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[255] Captain C.D. Howard-Johnston, DAUD, and Captain N.A. Prichard, DASW, Ref: D.559 (Draft), 5 August 1945, ADM 1/17653.
[256] 'Operation "CW": Analysis for NW Approaches, 25 August – 17 October 1944,' W.H. McCrea, DNOR, 1 December 1944, ADM 1/17653, p. 15.
[257] [Report of Proceedings of 9th Escort Group for period 7 October to 3 November 1944], Commander Layard, Senior Officer, EG9, 7 November 1944, ADM 217/728.
[258] 'Sunday, 3 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

(b) A/S teams required practice to realise the effect of tide on the plotted movements of bottomed contact, and on the problems of holding contact and attacking them. They also required practice in the techniques of classification by echo sounder.[259]

In some ways these were the easier aspects to correct. Professor McCrea, having analysed the A/S operations from the beginning of September up to the end of 1944, thought it was also vital that training be given in the greatest problem of A/S operations in inshore waters which was that of initial detection. Howard-Johnston agreed that this was a weak spot in the training and undertook to discuss it with DASW and then Western Approaches.[260] Yet, even with these shortfalls the British position was unlike the period at the beginning of the war. Now the British commanded an adequate level of combat strength and a training machine able to instil the necessary skills to counter the German onslaught. During the last weeks of the war, the enemy was beginning to find the losses unacceptable and had withdrawn most of his U-boats from British coastal waters, except off the East Coast, and was trying to operate them in the more distant South-West Approaches. In McCrea's opinion, the campaign ended in a victory for British forces. Overall it had been one of a great deal of improvisation on both sides, though the Allies were more adept at responding to German initiatives.[261] But McCrea warned that such an optimistic view needed to be balanced against the future threat of the new, fast U-boats. Of course, much of the focus of the British planning effort was in preparing for a U-boat campaign in which the Type XXI and Walter high-speed U-boats would have played a prominent part. In the event these boats were not ready in time.

Prospects of the U-boat War

There was general agreement with Captain Winn's view that the prospects in the anti-submarine war were heavily dependent on the character and ability of individual U-boat commanders.[262] Horton, for one, saw that his task was

> ...to destroy as many as possible of the existing U-boats, thus preventing experienced officers and men from manning the new types. He also hoped to damp their enthusiasm by continually hammering at morale.[263]

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[259] Captain C.D. Howard-Johnston, DAUD, and Captain N.A. Prichard, DASW, Ref: D.559 (Draft), 5 August 1945, ADM 1/17653.
[260] 'A/S Training for Operations in Inshore Waters,' W.H. McCrea, DNOR, Report No. 83/45, 8 January 1945, ADM 219/283.
[261] Doug McLean, 'The U.S. Navy and the U-Boat Inshore Offensive,' in William B. Cougar (ed.), *New Interpretations in Naval History: Selected Papers from the Twelfth Naval History Symposium* (Annapolis: Naval Institute Press, 1997), pp. 310-324.
[262] 'U-boat Situation, Week Ending 11 September 1944,' Captain Rodger Winn, RNVR, OIC/SI.1078, n.d., ADM 223/172.
[263] W.S. Chalmers, *Max Horton and the Western Approaches* (London: Hodder and Stoughton, 1954), p. 212.

Principal among these new U-boats was the ocean-going, schnorkel equipped Type XXI. Their streamlined hulls would make them hard to detect, especially end-on, and with their high underwater speed, thought to be in the order of 13-15 knots, they would be difficult to attack with existing equipment. If they were also commanded by experienced men they could pose a substantially greater threat than the existing schnorkel-fitted U-boats, both in the ocean and in inshore waters. Large numbers of these boats were known to be working-up in the Baltic, with some 15 expected to be operational by the end of 1944 and perhaps 95 by April 1945. Trials were being carried out to investigate tactics to counter these fast U-boats, as will be described in the next chapter. Meanwhile, as Horton pointed out, the immediate issue facing the anti-submarine forces was the normal schnorkel-fitted U-boat. The challenge was to devise counter-measures that would combat this threat, and at the same time delay or dilute the forthcoming problem of the Type XXI.

Certain material measures were readily adopted, including the formation of more escort groups. Other, more innovative but more complex, developments were undertaken. For example, it was hoped that a new scheme to reduce the ship's propeller noise and the use of off-board, expendable noise-makers to deflect Gnat attacks, would both lead to improved asdic performance in shallow waters. Asymmetric A/S measures were also taken. These included use of concrete-piercing bombs for attacks on U-boat pens, increased defensive A/S mining off convoy routes and offensive mining of U-boat training areas, the use of US Magnetic Anomaly Detection equipment and better means of marking the position of wrecks were all considered at an early stage.[264] At the end of November 1944, Professor E.J. Williams in DNOR produced a '...tentative and provisional...' paper, which drew on earlier work and the shape of which, he thought, might be useful for the next Cabinet Anti-U-boat Committee. Williams calculated that the schnorkel was probably 20 times more difficult to detect and attack by aircraft than a surfaced U-boat, especially by night and estimated that '...asdic <u>search</u> (as distinct from attack) has only been about 20% of its value in average ocean conditions.' Nevertheless, Williams noted, experience had shown that once found, the chance of killing a U-boat exceeded earlier figures for open ocean hunts. This, Williams thought, was because shallow water reduced the

[264] 'Minutes of the Meeting held at 10, Downing Street, SW1 on Tuesday, 31 October, 1944, at 6.0 pm,' AU(44) 3rd Meeting, War Cabinet Anti-U-boat Warfare, CAB 86/6, pp. 3-4.

uncertainty in depth estimation, and, more importantly reduced the dead time between firing and explosion of the A/S projectiles.[265]

The bulk of Williams' paper, approved by DNOR, Professor P.M.S. Blackett, was incorporated into a note by Howard-Johnston which he drafted at the end of November in consultation with Winn and DASW. They concluded that the enemy had sunk one ship for every three U-boat cruises, and had lost a U-boat for every two ships sunk. This dismal performance was, however, expected to be overtaken in a renewed offensive in the New Year, which would include the new U-boat types. Howard-Johnston concluded that as many as 160-200 ships could be sunk during the first three months of 1945, half of them by the Type XXIs. The countermeasures identified reinforced those already being developed, that is, the concentration of more escort groups in inshore waters along with intensive training, the extensive use of A/S mining, and bombing attacks on U-boat construction yards and oil supplies.[266] Howard-Johnston's note was reviewed by ACNS(UT), Rear Admiral J.H. Edelsten. The losses attributed to the Type XXI were reduced by half, perhaps because there was more awareness of the difficulties of operating the Type XXI effectively in submerged pack operations because of communications difficulties and the encouraging results obtained during the recent trials with a fast British submarine which confirmed that the problems of detection and attack were tractable.[267] The total casualties anticipated were therefore some 120 ships during the first three months of 1945, a number, Edelsten remarked, which could be heavily influenced by the degree of offensive spirit exhibited by the U-boats, which remained the unknown factor.[268] Although the forecast figures were altered Edelsten's paper was broadly accepted and formed the basis for subsequent appreciations by the First Sea Lord, Admiral of the Fleet A.B. Cunningham, in his submissions to the other Chiefs of Staff, and the Cabinet Anti-U-Boat Warfare Committee.[269]

In addition to his discussion with Williams, Winn and Prichard, Howard-Johnston had also asked a former colleague in DAUD, Commander H.W. Fawcett, RN (Retd), to

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[265] 'Prospects in the U-boat War,' E.J. Williams, ADNOR, Report No. 81/44, 17 November 1944, ADM 219/161, p. 1.
[266] 'Review of U-boat Results in Inshore Waters, Period 1 July to 31 October,' Captain C.D. Howard-Johnston, DAUD, Ref: D.294, 23 November 1944, ADM 223/20, pp. 1-3.
[267] 'Monthly Anti-Submarine Report, August 1944,' 15 September 1944, ADM 199/2061; 'Monthly Anti-Submarine Report, November 1944,' 15 December 1944, ADM 199/2061.
[268] 'Review of U-boat Results in Inshore Waters,' Admiral Edelsten, ACNS(UT), UT.37, 30 November 1944, ADM 205/36.
[269] 'A Forecast of the Results of the U-boat Campaign during 1945, Memorandum by the First Sea Lord,' Admiral of the Fleet A.B. Cunningham, COS(45)14(0), 6 January 1945, PREM 3/414/1.

offer his views on the coming U-boat offensive. Fawcett was an A/S specialist, with experience of the First World War and who had served in DASW and then for a year in DAUD, where he had been involved in tactical appreciations, along with Leon Solomon of DNOR. Solomon, and it seems Fawcett, was indoctrinated into Special Intelligence. Fawcett was now attached to Captain Peyton-Ward's staff at Coastal Command and, Howard-Johnston thought, was a man not only of ideas but '...willing [and] able to back them up with statistics.'[270] Unfortunately, Fawcett's ideas arrived too late to affect Howard-Johnston's paper, but echoed the concepts abroad in the Naval Staff. Wider opportunities for destroying U-boats had to be found Fawcett thought, because the schnorkel had reduced the overall killing power of aircraft and escorts to a tenth of their former value. Concentration on purely "defensive" measures would mean that too many merchant ships would be sunk for every U-boat that was destroyed, and this would not be enough to "get their tails down". Offensive action was needed, too, especially against the new fast U-boats. This, he hoped would be possible due to the excellent U-boat tracking from intelligence, even if this was not as accurate as formerly because U-boat traffic was now not so voluminous. In any case his ideas did not depend on precision targeting of U-boats. Instead what he had in mind was an "obstacle race" consisting of the whole gamut of action ranging from bombing of building yards and factories, bombing and mining of bases (including attacking enemy minesweepers to prevent mine clearance), attacking enemy supply shipping serving the U-boats bases, use of Allied submarines off those bases, continuous anti-submarine air cover over U-boat transit routes and intercept them with A/S vessels, and, of course, surface and air escort of Allied convoys. Fawcett analogy was: 'If we put 100 horses over a steeplechase course consisting of six jumps each of which is cleared by 96% of the horses, then only 78 horses finish the course. This concept, as Fawcett pointed out, had a resonance with the strategy employed in the First World War.[271] The key was that defensive and offensive measures were not seen as alternatives. Instead they were mutually interactive.

In reviewing the 1944-45 inshore campaign against the schnorkel-fitted U-boats Professor McCrea noted the poor asdic performance of the escorts but concluded that it was '...the high U-boat density which permitted a satisfactory outcome despite this low efficiency.' This was demonstrated by the statistics. Of the 37 U-boats sunk by A/S ships, only 2 were detected in the first place by radar and 2 visually. The rest were

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[270] Howard-Johnston, DAUD, to Fawcett, SNLO Coastal Command, Ref. D.327, 26 December 1944, CCAC, FWCT 2/4/5.
[271] 'Possibilities of the Coming U-boat Offensive [April 1945],' H.W. Fawcett, Naval Staff, Coastal Command, 1 December 1944, CCAC, FWCT 2/4/5, pp. 1-2 and 5.

initially detected by asdic. Only about six of the U-boats were detected at night, which '...probably was connected with the fact that the U-boats wanted to attack by day and so were more likely to be in the patrolled areas then.'[272] Commander P.W. Burnett, Senior Officer of EG10, wrote in early 1945:

> The five confirmed U-boats with which I have been in contact in the last year have all been detected by asdic, without any pervious warning of their immediate presence. Although several others must have been swept over, these five have all been detected by day.[273]

McCrea also realized that to understand how factors such as the weather affected U-boat operations '...as regards schnorkelling, sighting, attacking, etc. would require a big investigation.' It does not appear that this was done, nor did McCrea have time before the war ended to assess whether the disposition of the escorts was the best to take advantage of opportunities to detect U-boats approaching a convoy to attack. Once the Admiralty took possession of the German records, McCrea thought it entirely possible for a detailed analyses to be done, which would identify dispositions around convoys which would ensure that the most probable positions from which the U-boat fired were swept over by as many escorts as possible. Howard-Johnston was of a like mind. He asked '...for three months with my Division to analyse every U-boat incident when the U-boat got away. ...But my Division was closed down immediately after VJ-Day and the analysis was never done.'[274] The Admiralty drafted a short paper intended for consumption by the British and Americans in the Pacific preparing for the invasion of Japan. It contained the main lessons from the inshore campaign Howard-Johnston in conjunction with Captain N.A. Prichard, DASW, emphasized

> The marked deterrent effect of strong patrols which attack all suspicious contacts without undue regard to conservation of ammunition is apparent from German records now available. In particular the value of aircraft patrols may be out of all proportion to the number of U-boats they sink.

The Directors jointly recommended that

> ...aircraft should patrol in order to detect U-boats charging, rather than fly close escort duties. If there are any spare after the area in which the U-boats must charge has been saturated (i.e. each point is swept over at least every hour) they are better used as extended escorts by night rather than as close escort trying to detect submerged U-boats by day.

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[272] 'Survey of A/U Operations...,' ADM 1/17653, pp. 7-8.
[273] 'Narrative and Remarks by Senior Officer,' Section I, Part 1, 'Report of Proceedings,' Commander P.W. Burnett, RN, HMS *Braithwaite*, Ref. No. 1A/10, 20 February 1945, ADM 199/198, pp. 29-30.
[274] C.D. Howard-Johnston to J.D. Brown, NHB, 24 February 1980, CCAC, HWJN. [emphasis supplied]

However, direct convoy protection by surface escorts remained their central concern. 'The necessity,' Howard-Johnston and Prichard wrote

> of guarding against submerged attack by a U-boat which remains bottomed until the last moment, and of investigating innumerable asdic contacts, has resulted in changes in [convoy] Screening Diagrams.

These changes were briefly stated:

> An advanced screen has not time to differentiate between the many non-sub contacts and a U-boat lying "doggo", though there is a good chance of detection if the U-boat is manoeuvring to attack. A/S vessels should, therefore, be formed into a comparatively dense screen closer ahead than has been usual. When this requirement has been met any remaining vessels may be disposed astern ready to deliver quick counter-attacks after a torpedoing, or be placed in positions on the bow or beam which would be suitable firing positions for a U-boat.[275]

In the event the abrupt end of the war in the Far East forestalled the despatch of the paper. The lessons were not forgotten, for when Burnett was later appointed to the Admiralty, he was to use his wartime experiences and long-term professional knowledge when re-assessing A/S warfare doctrine. However, before covering these events, the way the Admiralty dealt with the incipient threat of the fast submarine is examined in the following Chapter.

[275] Captain C.D. Howard-Johnston, DAUD, and Captain N.A. Prichard, DASW, Ref: D.559 (Draft), 5 August 1945, ADM 1/17653.

Chapter 4: The Dawn of Modern Anti-Submarine Warfare, 1944-1946

The Problem of the Fast U-boat

By mid-1942, the ubiquity and increasing effectiveness of Allied anti-submarine counter-measures had impelled Dönitz to press for the technical means to employ submerged U-boat operations for the remainder of the war. Conversion of existing types with the schnorkel was only a short-term palliative because of their low underwater mobility. What was needed was a U-boat with high underwater speed and endurance. This, it seemed, could be achieved by accelerating the development of novel submarine types powered by the Walter turbine, which could be run submerged, powered by the decomposition of oxygen-bearing hydrogen-peroxide fuel. High submerged speed was achieved by sacrificing surface performance and optimizing the streamlined hull for underwater travel. However, as the technical difficulties with the system became more apparent, it was soon realized that they would prevent this type becoming operational in the near-term. Development was therefore started on a hybrid U-boat, combining the Walter-boat's streamlined hull, with a powerful, but conventional, diesel-electric propulsion train and a very large battery, capable of being recharged while submerged by using the schnorkel. This was the Type XXI U-boat.[276]

During the winter of 1943-44 NID suspected that the Germans were developing new U-boat types, although their exact nature remained obscure until Spring 1944, when the Type XXI U-boat was identified.[277] Captain Prichard, DASW, rapidly drew on the existing Admiralty expertise to define the measures necessary to counter this new threat. Prichard quickly concluded that such a U-boat, which was assessed to have an extreme diving depth, long endurance and high underwater speed, would be able to make long submerged approaches to convoys from any direction, making all-round convoy protection necessary at greater distances than previously. The Type XXI could also operate stealthily at slow speed, but be able to use high speed to evade A/S vessels. A single escort was unlikely to be able to hold contact and would need the help of a consort. Even so, attacks would be difficult, given the U-boat's high manoeuvrability. Depth-charge attacks were likely to be ineffective and, although ATWs

[276] Doenitz, *Memoirs*, p. 265.
[277] M. Llewellyn-Jones, 'British Responses to the U-boat, Winter 1943 to Spring 1945' (MA, London, King's College, December 1997), pp. 7-11.

offered the best chance of success, their short range, combined with high-speed evasion by the U-boat, would make attacks highly dynamic, and accurate aiming difficult because the rate of change in the target's bearing would be close to the maximum turning rate of the attacking ship. During an approach, A/S ships would have to be wary of counter-attacks by the U-boat with the Gnat. Counter-measures, such as the "Step Aside" tactics, or reducing speed, would delay the approach and give the Type XXI ample time to avoid the escort. A high speed approach degraded asdic performance and the escort risked overrunning the U-boat.[278]

A brief, provisional appreciation of the Type XXI U-boat was issued to the Fleet in September 1944 by Captain Howard-Johnston, DAUD, in the Monthly Anti-Submarine Report.[279] The article was based on a more detailed analysis by Professor E.J. Williams, of DNOR, who was one of the Special Intelligence confidants. His paper was therefore based on recent Ultra material.[280] This intelligence revealed that the Type XXI U-boat was about 245 feet in length, with a displacement of 1,600 tons, a submerged speed of 17 knots and long endurance from its abnormally large battery. Not only did this information allow the earlier assessment of the Type XXI to be refined, but it undoubtedly provided the impetus for potential counter-measures to be analysed and exercised on the tactical table at the Western Approaches Tactical Unit (WATU) in Liverpool under the guidance of Captain G.H. Roberts and, on occasion, with DNOR scientists.[281] As Captain Howard-Johnston later recalled the convoy system would still have been the most effective means of defeating the Type XXI U-boat, especially as it could have benefited more from independent routing of trade than the ordinary U-boats.[282] Essentially, these theoretical and practical investigations suggested that the Type XXI's higher speed meant that the area into which it could escape would increase exponentially and this, in turn, would substantially reduce the effectiveness of the escorts' asdic searches, unless they could arrive at, and cover, the area quickly. However, at high speed, the Type XXI might make enough HE noise to give the escorts a chance of detecting the U-boat. There remained the problem of attacking the Type XXI, for it could use its high submerged speed and rapid acceleration to prevent an

[278] 'Deep and/or Fast U-boats,' Captain HMA/SEE, Fairlie to DASW, 10 April 1944, ADM 1/16495.
[279] 'The Type XXI U-boat - A Provisional Appreciation,' in, 'Monthly Anti-Submarine Report, August 1944,' 15 September 1944, ADM 199/2061, pp. 17-19.
[280] 'Type XXI U-boat (A Provisional Appreciation),' E.J. Williams, DOR/44/68, 4 September 1944, ADM 219/150.
[281] Professor Sir William McCrea, FRS, Interview, 17 April 1998; 'Tactics against Fast Submerged U-Boats,' A/Commander J. Plomer, RCNVR, Director of the Combined Tactical Unit to Captain (D), Halifax, 25 November 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.
[282] C.D. Howard-Johnston to J.D. Brown, NHB, 24 February 1980, CCAC, HWJN.

escort settling in on the asdic echo. What was needed were new HE tracking tactics, and greater reliance on ahead throwing weapons.

HM Submarine *Seraph* Trials [283]

In October 1943, when the prospect of a German U-boat with high underwater speed was emerging, NID requested Charles Lillicrap, Director of Naval Construction (DNC), to investigate the possibility of providing a British fast underwater target. Lillicrap had concluded that by streamlining the hull and removing all the appendages required for fighting, including the deck gun, a British submarine could achieve a submerged speed of 13 knots for about 20 minutes.[284] So, when Dr. Goodeve, the Assistant Controller (Research and Development), convened a meeting on 6 June 1944 to discuss the Type XXI threat, Lillicrap was ready with outline proposals for a fast underwater target that could be used to test existing British A/S equipment and tactics. HM Submarine *Seraph*, awaiting repairs after a diving accident, was the boat selected and thereafter events moved rapidly. At the Deputy Controller's Meeting a week later it was agreed, anticipating formal approval, that conversion work was to start immediately, with completion due at the end of August. The modifications fell into three parts. Firstly, her main electric motors were up-rated and propellers with coarser pitch were fitted, so that *Seraph* could develop greater propulsive power. Secondly, her hull was streamlined by the removal of guns, the fairing off of apertures and a reduction in the size of the hydroplanes and conning tower. These modifications reduced the hydrodynamic drag by 55%, while the propulsion power was increased by 13% {*Plate 17*}. Thirdly, a high capacity battery was installed to extend her underwater endurance. The results were impressive, for when *Seraph* began her high-speed trials towards the end of September the speed and endurance figures showed a significant improvement, especially in her endurance at medium speeds:–

Speed	*Seraph's* Endurance	
	Before conversion	After conversion
4 knots	14 hrs.	35 hrs.
6 knots	4 hrs.	8 hrs.
10 knots	–	2 hrs.
12 knots	–	¾ hr.[285]

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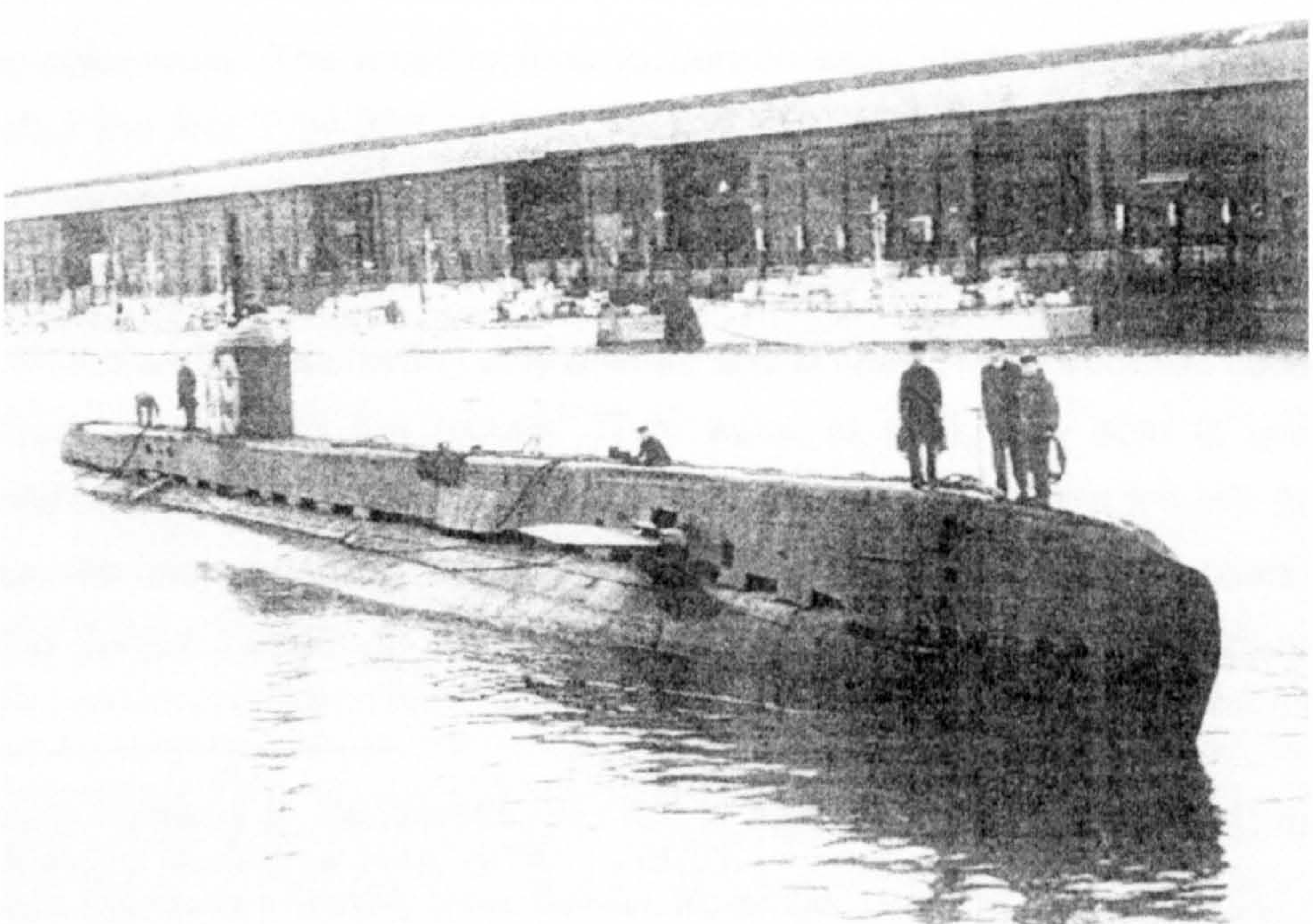
[283] Llewellyn-Jones, 'Trials with HM Submarine *Seraph*', *passim*.
[284] 'Underwater Internal Combustion Propulsion – General Considerations,' n.d., RNSM A1948/009.
[285] 'The Trend of Submarine Design,' Lecture by RN Newton, RCNC, DNC Department, November 1945, RNSM A1991/058, p. 5; 'HMS *Seraph* (*P.219*) First of Class Trials, September 1944,' Office of Admiral (S/M), RNSM A1991/250, p. 8.

Plate 17: HMS/m *Seraph* Before and After Conversion

(IWM A.21104 and 'Monthly Anti-Submarine Report, November 1944', 15 December 1944, ADM 199/2061, Opposite p. 20.)

Seraph Before Conversion



Seraph After Conversion

Of course, these figures are slightly misleading, since lacking a schnorkel, *Seraph* had no method of replenishing the air inside the boat. It was realized that the crew's concentration would deteriorate after about 12 hours dived, though classic symptoms of carbon dioxide poisoning and oxygen lack would not become evident for another five hours. The greatest problem was that *Seraph* could not recharge her battery at sea, and this limited her value in tactical exercises.

At the end of September 1944 *Seraph* carried out a series of asdic and tactical trials, the first with HMS *Kingfisher* and the latter with the EG19. The trials' teams included Professor W.M. McCrea from DNOR in the Admiralty and J.A. Hakes, a scientist from the nearby HMA/SEE, Fairlie.[286] The tactical trials were organized by Admiral Horton, Commander-in-Chief, Western Approaches' Headquarters in co-operation with representatives of Commander US Forces in Europe, RAF Coastal Command and Naval Aviation, Flag Officer (Submarines), and the Directors of the Anti-U-boat, Anti-Submarine Warfare, Naval Intelligence, and Naval Operational Research Divisions, as well as training and experimental establishments. At sea, the trials were controlled by Lieutenant Commander D.R. Mitchell, DSO, DSC, who was now part of the training staff onboard *Philante*. For the tactical trials Mitchell assumed the title of Training Commander, "Rockabill", denoting the area of the Irish Sea where the trials took place.[287] It was intended that the tactical settings for the trials reflect the work done at WATU and pre-trial practice was carried out ashore in the HMA/SEE attack teacher. It can be seen, then, that these trials brought together the full weight of the Admiralty, the operational commands (including their training organization), and the scientific community. The modifications to *Seraph* were started on 16 June, just one month after the first Type XXI, *U-2501*, was launched. Subsequent trials with *Seraph* were run some seven months before the first operational cruise by a Type XXI, *U-2511*.[288]

With the asdic trials lasting only a week and in changeable acoustic conditions, it was difficult to correlate the results. They were, at best, only able to give rough indications of echo and HE strengths. Nevertheless, the data were adequate to provide more realistic information for the continuing tactical table trials. These trials showed that, while *Seraph*'s beam-on asdic echo was little changed, at fine inclinations it was

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[286] Interview, Professor Sir William McCrea FRS, 17 April 1998; 'Monthly Log of HM Submarine *Seraph*, Month of September 1944,' ADM 173/18701.
[287] 'Western Approaches Monthly News Bulletin, November 1944,' 18 December 1944, Box 396, RG 38, NARA2.
[288] David Syrett (ed.), *The Battle of the Atlantic and Signals Intelligence: U-Boat Situations and Trends, 1941-1945* (Aldershot: Ashgate, 1998), p. 423 fn. 624.

much smaller and, consequently, asdic ranges on these bearings were reduced by three-quarters or more. It is likely at this stage of scientific understanding that asdic echoes were thought to be returned from the outer surfaces of the submarine.[289] In fact the sound also penetrated to the inner (pressure) hull and reflections could occur from "internal" structures. These additional reflected highlights probably contributed to the uneven echo pattern observed. At fine inclinations, when *Seraph* was travelling at high speed, the echo's doppler allowed the operators to distinguish even the weak echo against the background noise and other interfering echoes. For example, although *Seraph* at 12 knots had been held on the asdic recorder at only 750 yards stern-on, her echo, picked out by the doppler, was heard out to 2,700 yards. It was also discovered that the streamlined *Seraph*'s HE was weaker when compared to her pre-converted state. This was because less power was needed to turn her propellers and they turned at a slower rate, to propel her at any given speed. They were therefore less likely to cavitate and gave her a higher "silent" speed.[290] Thus when *Seraph* was travelling at 6 knots, or less, *Kingfisher* could not detect any HE from her; even at ranges as short as 500 yards. But, as *Seraph's* speed rose above 6 knots, her HE became easily detectable. The HE rapidly increased in intensity, reaching a peak at 9 knots and remaining at this level even as *Seraph's* speed increased to 12 knots. At these speeds the submarine's HE could be detected by *Kingfisher* at up to 5,000 yards, though because there was no transmission-echo elapse time range could not be measured, and only a bearing found. Unfortunately, for an escort to keep up with a fast submarine, her own speed would create a great deal of self-noise, so that for speeds above 16 knots the asdic range might be reduced by 45% and HE detection range by 50-60%.

There were thus complex interactions between submarine and ship speeds, and relative orientation, and the resultant detection range that could be achieved. Nevertheless, the HE ranges seemed remarkably constant and unaffected either by water conditions (which caused wild fluctuations in echo ranges), or the submarine's depth, though McCrea wondered whether this would hold true for the Type XXI, which was assessed to be able to dive to great depths. For, it was thought that while HE ranges would increase with target speed, as the submarine went deeper the HE range was likely to decrease markedly because the greater pressure at depth would inhibit the onset of propeller cavitation. This finding was consistent with the experiments by Directorate of Scientific Research and the Admiralty Research Laboratory, at Teddington. *Seraph* had only operated down to 200 feet (the limitation possibly

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[289] See Appendix 2.
[290] D.C.R. Webb, Letter, 6 August 1997; Peter Evans, E-mail, 22 December 1998.

imposed by structural weakness caused during her accidental dive in May 1944). However, the interaction between speed and depth was by no means linear. Post-war trials with a Type XXI showed HE levels at 6 knots reducing significantly between 50 and 150ft, while at 10 knots they remained unchanged, and at 15 knots the HE level increased marginally.[291] Thus, while target HE could not be guaranteed, its use was important for two reasons. Firstly, the HE was sometimes loud enough to mask the asdic echo, not only on the recorder but aurally too, so that HE might be the only means of holding contact. Secondly, with an asdic that transmitted a narrow "searchlight" beam, there was little margin of error when holding contact on a high-speed submarine. The submarine could rapidly move outside the asdic beam and escorts '...could easily be thrown off the scent,' especially if operating singly.[292] However, the asdic could be used to sweep for HE about 10 times more rapidly than probing for an echo over a wide angle. Once the target's bearing was established the asdic could transmit once again to obtain an echo.

Subsequent tactics would depend on whether the escort was able to gain asdic contact, or had to rely only on HE bearings. The problem here was that the speed at which an escort was likely to hear HE would probably be less than the speed at which the U-boat was travelling. So, in order to close, the escort would have to employ bursts of high speed interspersed with periods of slow speed to listen for the HE. If the proportion of slow speed was kept to a minimum (typically 25%) it was found possible to close a conventional U-boat. However, especially when deep it was found that the U-boat's wake would mask the HE from its propeller if the escort was within 20° of directly astern. Care had to be taken during the periods of high speed not to overrun the U-boat, should it slow down, or to mistake own ship HE for that of the submarine. It was recommended, therefore, that the escort's speed should be reduced to carry out a listening sweep at least every 5 minutes. There was also the danger of the U-boat counter-attacking with a Gnat. In any case it was desirable for asdic contact to be gained as soon as possible.[293]

These features concentrate on the high maximum speed of the new submarines and is emphasized in nearly all the post-war literature on the Type XXI. However, both to conserve battery power, and to reduce the chance of its HE being detected, a high-

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[291] 'Dependence of Submarine Propeller Noise on Depth of Submarine,' Director of Scientific Research, SRE/SM/7/0, 19 June 1944, ADM 283/13; Urick, *Principles of Underwater Sound*, p. 338.
[292] Telephone Interview, Rear Admiral J.H. Adams, CB, LVO, 2 March 1999.
[293] 'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2, paragraphs 188-189.

speed U-boat was likely to make use of its long endurance at higher "silent" speed to avoid contact by escorts.[294] Initial tactical planning of counter-measures had to take account of both the potential of a U-boat making off (at least initially) at high speed, before carrying out its main evasion at silent speed. The key was to get the escorts near to the submarine's datum position as quickly as possible. This was complicated by the need to take anti-Gnat precautions. Most ships could not approach at high enough speed to be safe, and using Foxers made so much noise that the chance of gaining contact was greatly reduced. To this end existing procedures were adapted, with the nearest ship executing an immediate reaction "Delta" search, bringing her over the datum, while making allowance for the threat of a Gnat counter-attack (by the "step-aside" manoeuvre). The next ship to join was to start a "Double Observant" square search, four miles out from the submarine's diving position. She was to be joined by the first ship on completion of the Plan "Delta". Thus the Plan "Delta" would cover the possibility of the U-boat remaining in the vicinity of the datum, while the "Double Observant" was designed to catch the submarine if it evaded at 12 knots. However, it proved impracticable to play out these tactics at sea because of *Seraph's* limited high speed endurance. Instead tactical investigations continued ashore using a tactical table, while the sea trials concentrated on attack procedures.

The main trials effort by the EG19 was therefore directed towards exploring the problems involved in attacking a fast U-boat. It was assumed that ahead throwing weapons gave the highest probability of success but it was necessary to establish whether the Type 144 asdic-fitted escorts could apply the necessary deflection at the instant of firing to allow for the submarine's movement during the flight of the projectiles. The ship's anti-submarine teams had practiced the procedures ashore in HMA/SEE's attack-teacher and had achieved successful attacks, though there were many practical operating difficulties, as well as random errors, that were likely to reduce the overall accuracy of attacks. Howard-Johnston, quoting Lieutenant Commander Mitchell, warned that

> "...the difficulty in attacking [was] primarily due, not to the unsuitability of ships or instruments...but to the very reduced margin or error which [*Seraph's*] high speed permits the hunting ships."[295]

Even so, when *Seraph* took modest avoiding action attacks were possible, provided a recordable echo was received. Up to submarine speeds of 12 knots it seemed that, with adequate training, asdic teams could operate the cumbersome "cut-on" procedure

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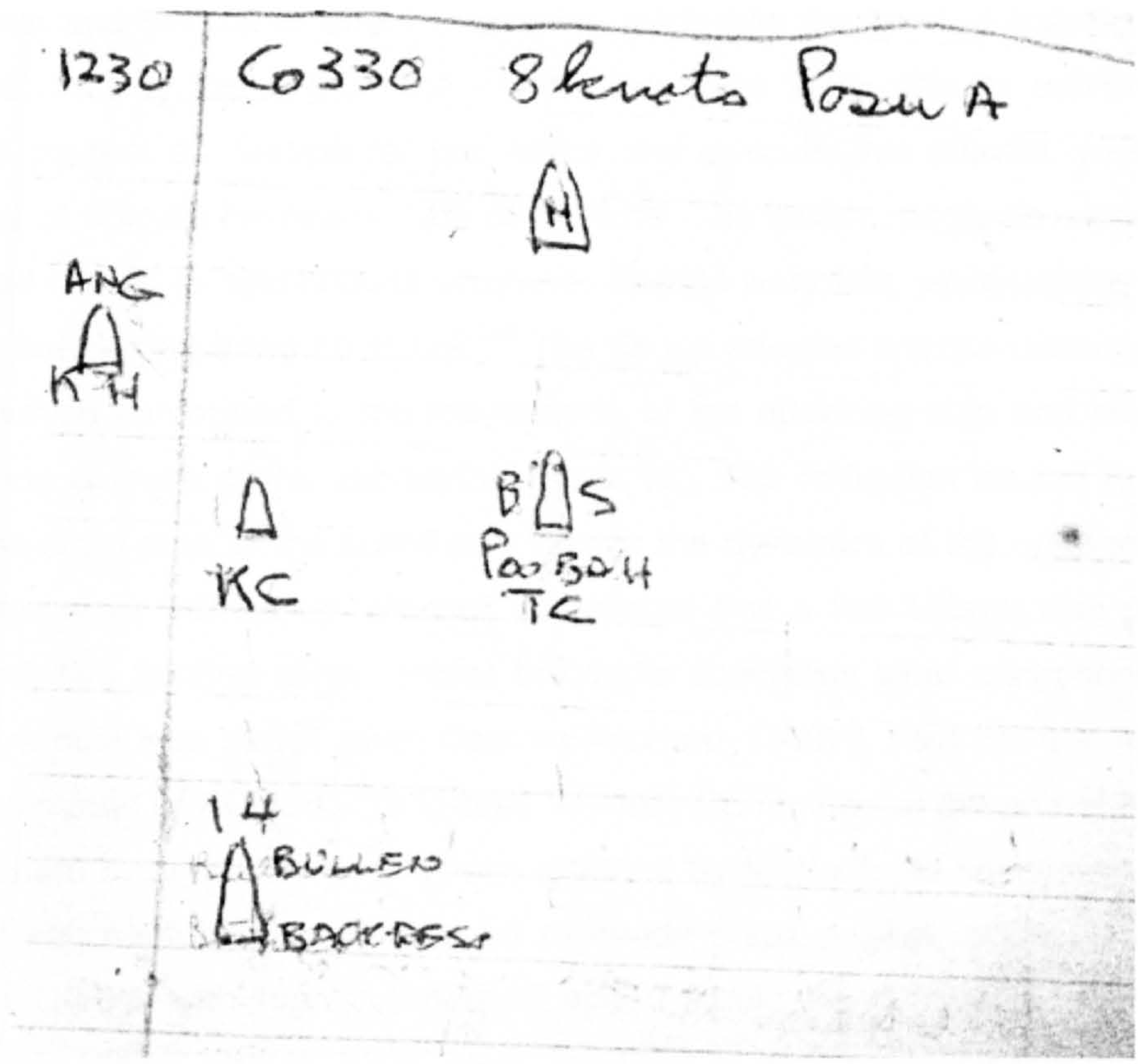
[294] Hessler, *The U-boat War*, Vol. III, p. 86.
[295] Quoted in 'Monthly Anti-Submarine Report, November 1944,' 15 December 1944, ADM 199/2061, p. 21.

Plate 18: Four Ship Tactic (Mallet's notebook)

MLJ



Mallet's Notebook showing disposition of EG19 against *Seraph* (which is not depicted but would be top-left where picture is annotated with "Co330") to determine the target's bearing and generate adequate fire-control solutions for an ATW attack. Professor McCrea sounded a prescient note of caution. The Type XXI U-boat's higher assessed speed of some 15-17 knots might just be enough to tip the dynamic tactical balance in favour of the submarine, and perhaps make countering the Type XXI an insurmountable problem.[296]

Admiral Horton reported to the Cabinet Anti-U-Boat Committee after the trials, that EG19, a '...particularly experienced group had had no success during the first week of such exercises, but had rapidly improved thereafter.'[297] Initially, *Seraph* proved to be elusive and difficult to attack. However, such was the level of training amongst the escorts, that by the end of the period, the ships were able to achieve almost continuous contact on *Seraph* for two hours and execute five attacks, even though *Seraph* was at 9 knots for nearly 40% of the time. The tactics, partly developed by the Group, used the HE to hold contact whenever *Seraph* went fast, while waiting for her to slow down before delivering an attack.[298] The Group adopted a loose diamond-shaped formation which conformed to the movements of the attacking ship and covered the likely evasion courses of the submarine {Plate 18}. The formation tended to gravitate towards the stern arcs of the submarine due to the dynamics of the engagements.[299] When teams were worked up, Mitchell considered that a fast U-boat was unlikely to escape from two hunting ships, unless the asdic conditions were exceptionally poor. This positive note was struck when Captain Prichard, DASW, held the first meeting of the sub-committee of ACNS(UT)'s U-boat Warfare Committee at the end of November 1944. Pritchard reported the conclusions reached by Mitchell. He concluded that a U-boat could successfully use high speed to evade ships only in rough weather and, although a U-boat with high submerged speed would be difficult to attack, highly trained ship's teams should have good chances of success. Commander-in-Chief, Western Approaches' representative, added that

> ...further exercises had proved that training in attacks on a fast submarine was 90 per cent of the battle. It had also been proved that ships fitted with the bearing

[296] 'Notes on A/S Trials with a Fast Submarine,' W.H. McCrea, Report No. 72/44, 9 October 1944, ADM 219/154; 'Notes on A/S Trials with a Fast Submarine, "Rockabill", 10-30 October 1944,' [W.H. McCrea], Report No. 80/44, 11 November 1944, ADM 219/160; 'Asdic Trials with HM S/M *Seraph* as Target,' J.A. Hakes, Research Note No. 53, HMA/SEE Fairlie, November 1944. DERA, AN 28144.
[297] 'Minutes of the Meeting...,' AU(44) 3rd Meeting, CAB 86/6, p. 24.
[298] 'The Use of Squid against the 25 knot U-Boat,' [Captain N.A. Prichard], DASW, [ASW 945/45], 30 June 1945, ADM 1/17591, p. 3.
[299] Paul Mallett, Letter, 7 July 1999; 'EG2: D-Day to VE,' Ron Curtis, June 1997, MLJ.

> recorder and helmsman's indicator (Asdic Type 144) had a tremendous advantage over ships not so fitted.[300]

In Mitchell's view, there were no grounds for changing established pair-ship tactics. More ships would simply get in the way and should carry out a containing "Box" search round the close A/S action. A contemporary American report summarised the issues, by noting that:

> The appearance of the new German XXI submarine does not seem to present any radical new implications, but merely a more difficult presentation of already existing problems.[301]

DASW ended the discussion by saying that the exercises with *Seraph* showed that minor modification to asdic operating procedures were necessary. The principle one being the combining of two successive asdic sweeps from 80° left to 80° right of the ship's head, taking about 6 minutes, with two all-round HE sweeps, lasting about 40 seconds. This combined echo and listening procedure marginally reduced the asdic search efficiency, but gave a better chance of gaining HE contact if the U-boat was travelling at speed. In addition, the tactical trials with *Seraph* showed that two escorts, by exchanging simultaneously recorded HE bearings, could plot the intersection of the bearings and thereby locate the submarine, as had been suggested by an earlier DNOR theoretical study. The procedure relied heavily upon the efficiency of the plotting organization, and of rapid inter-ship communications. After the trials with *Seraph* a number of improvements to the asdic control were put in hand, designed to restore the efficiency of operation to that experienced with normal U-boats by providing automatic training of the sound beam to compensate for the relative movement of both ship and target, and devices to improve the use of the attack instruments.[302] Only in the longer term did improved detection gear and weapons become available. In the meantime, tactical adaptation could exploit the potential, and mitigate the limitations, of existing technology.

While considering the results of the trials with *Seraph*, McCrea thought that there might be some value in countering fast submarine with sonobuoys. These expendable radio sonobuoys consisted of a hydrophone suspended below a buoyant cylindrical case about 3 feet 5 inches long by 4½ inches in diameter. The sonobuoy was dropped

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[300] 'Minutes of the First Meeting of DASW's Sub-Committee of ACNS(UT)'s U-boat Warfare Committee held at the Admiralty on Thursday, 30 November 1944, (Copy)' Folder NSS 1271-22, Vol. 8080, RG 24, NAC.

[301] 'Memorandum for the File,' 28 November 1944, Enclosure (S) to 'High Speed Submarines – Report of Tests Against (Project No. 103),' T.A. Turner Commander Anti-Submarine Development Detachment, United States Atlantic Fleet, ASDD/A5-7 Serial: 0024, 6 April 1945, Box 4476, RG 313, NARA2.

[302] 'The Asdic and its Associated Weapons,' DERA, AN.15971, p. 8.

near a suspected U-boat contact and any sounds picked up on the hydrophone were transmitted by a radio set to the aircraft. The sonobuoys had a nominal life of about 4 hours, after which they self-scuttled. However, because of the acoustic frequencies at which these sonobuoys listened, their performance was likely to rapidly deteriorate as the target's depth increased.[303] It had originally been intended to follow the EG19's exercises with Coastal Command and the Fleet Air Arm trials but these were delayed and eventually flown spasmodically between November 1944 and April 1945 by Coastal Command's Air Sea Warfare Development Unit (ASWDU).[304] The sonobuoys used were American AN/CRT-1A types. The ASWDU concluded that the average detection range showed a tendency to increase as *Seraph*'s speed rose above 5 knots, with ranges in the order of 7-8,000 yards at speeds in the order of 12 knots. The results, however, were very dependent on the weather, so that when the sea state was greater than four the equipment ceased to be of much operational value. Although these results were encouraging, the trial contained no tactical element. *Seraph* was constrained to run in a straight line between pairs of sonobuoys at the prescribed speed and depth for the serial and the sonobuoys had to be launched by a range vessel, to avoid at least one-third of the buoys failing if they were launched from an aircraft. Even then, their performance deteriorated as the battery ran down. The sonobuoy technology, introduced '...prematurely, in 1943 after inadequate trials and with over-optimistic ideas of its performance' was not sufficiently mature until the 1950s for open ocean searches.[305]

Further Assessment of the Type XXI

The details of the *Seraph* trials had been passed to the Americans and during the spring of 1945 the USN repeated the *Seraph* trials with USS *R-1*, which had also been streamlined (though with no other structural or propulsive changes). *R-1*, like *Seraph* for the British, was then used for training at the USN Fleet Sonar School, Key West, Florida. In Britain, too, further studies were initiated, training programmes started at WATU and a programme of sea training with *Seraph* begun for British and Canadian

[303] 'Notes on A/S Trials with a Fast Submarine, "Rockabill", 10-30 October 1944,' [W.H. McCrea], Report No. 80/44, 11 November 1944, ADM 219/160, p. 4.
[304] 'Minutes of a Meeting held at ACHQ Liverpool on 3rd October 1944 to discuss a Programme of Schnorkel and other Trials and Practices,' Admiral Horton, 4 October 1944, ADM 1/16121, p. 4.
[305] Air Ministry, *The Origins and Development of Operational Research in the Royal Air Force* (London: HMSO, 1963), p. 96; ' "High Tea" Range Tests with a Fast Submarine,' ASWDU Report No. 45/16, 25 May 1945, AIR 65/175; 'Sonobuoy Range Tests,' 15 July 1944, AIR 65/115; 'The Use of Sonobuoy Equipment,' HQ Coastal Command Training Instruction No 28, dated 9 June 1944, AIR 15/584.

escort groups.[306] Some of the groups found the problem a difficult one, even when carrying out searches with five escorts on the tactical table, or attacking during sea practices.[307] The Type XXI would not always use high speed. The British thought that it would be used by the enemy to evade an aircraft or a ship (which the U-boat suspected had reported her position), to avoid an imminent attack during an A/S action, or to reach a favourable attacking position when approaching a convoy.[308]

For the time being, the British had to make the best of the equipment they had to hand and to optimize its performance by adapting existing tactics and procedures. Considerable work was done at the research establishments on the effects of the new U-boats' speed and manoeuvrability on A/S weapon performance, even though based on inadequate information. The trials with HMS *Seraph* had provided only a partial answer to the problem, because of the very limited time available to test equipment and tactics in all environmental conditions and against varying submarine tactics. The latter would, of course, be circumscribed by safety rules (though not to the same extent as in peacetime exercises).[309] Nevertheless, the trial results were seen by Captain R.J.R. Dendy, the Captain of HMA/SEE, to have been '...on the whole reassuring.'[310] Indeed the subsequent experience of high speed exercises with *Seraph*, and other converted S-class boats, suggested that certain factors weighted an engagement with a fast U-boat in favour of the hunting forces. While it was true that A/S attacks had occasionally to be broken off, the prominent HE had proved to be '...an aid to contact keeping, the prolongation of hunts and the provision of further opportunities for attack.' Also, due to the U-boat's relatively limited endurance at high speed the escorts could afford to wait until the U-boat slowed down before attempting an attack. Dendy was also comforted by the greater size of Type XXI, as against *Seraph*, or the captured Type VII, HMS *Graph*, so that the new U-boats would give stronger asdic returns and make them an easier target. The Mine Warfare Department produced a somewhat more cautious assessment that aligned more accurately with existing intelligence. They observed that the plan area of the Type XXI was only 20% greater than *Graph*, which was not crucial

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306 'Western Approaches Tactical Unit Annual Report - 1944,' Captain Gilbert Roberts, 18 December 1944, ADM 1/17557; Milner, *U-boat Hunters*, p. 215; McLean, 'The Last Cruel Winter', p. 99.
307 Commander A.F.C. Layard, Diary, 3-6 February 1945, RNM.
308 'HE Listening versus Transmitting by Asdic – Operational Considerations,' The Captain, HMS *Osprey*, to DASW, No. 636/86, dated 26 January 1945, ADM 1/17569.
309 Baker-Cresswell to Gretton, 5 October 1981, 'Battle of the Atlantic,' Gretton, 23 Part 1, 1 of 2, MS93/008, NMM(G).
310 'Fast U-boats,' Captain HMA/SEE, Fairlie to DASW, 28 March 1945, ADM 1/16495.

to success with either Squid or Hedgehog. This was more dependent on the U-boat's speed, depth and subsequent manoeuvres.[311]

As the European war drew to a close McCrea produced a somewhat bleak but perceptive analysis of the effects of high submerged speed and endurance on submarine tactics and their consequences for anti-submarine forces. Up to the middle of 1943, U-boats had operated in packs and, by remaining largely on the surface, had maximized the chance of one member of the pack sighting a convoy. The mobility conferred by surface operations meant that some 70-80% of the pack would intercept the convoy though, largely because of navigational difficulties, this would normally take two or three days. Without radar, the U-boats also had difficulty in remaining in contact, especially if forced to dive while the convoy executed an evasive turn. But it was the growing ubiquity of Allied air cover, which by 1944 forced the U-boat to spend two-thirds of their time submerged, that finally defeated the ability of the U-boat packs to locate and concentrate against convoys.[312] When aircraft were absent, the U-boats had normally been able to make an average transit speed of about 12 knots. Since most of the U-boat pack was able to make contact with the convoy within the first two days, the furthest U-boats would have converged from a range of some 500 miles. Assuming that navigation was no more difficult and that communications difficulties could be overcome, McCrea thought that a submarine operating entirely submerged, capable of an equivalent speed and endurance, that is, 12 knots for 48 hours, would achieve similar results. While beyond the capability of the Type XXI U-boat, McCrea thought that such performance could be developed within the next ten years.

The Germans had also tried to use pack tactics to overwhelm a convoy's defences by concentrating a large number of U-boats around a convoy and attacking simultaneously. This objective proved elusive. Indeed so great were

> ...his difficulties in bringing the majority of members of a pack into contact with the convoy sometime within the two or three days following an initial sighting, that the attainment of this primary objective represented about the limit of his capabilities. Once any particular U-boat gained contact it had to make the best of its individual opportunity and no attempt could be made to concert its action with that of another member of the pack.[313]

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[311] Captain R.J.R. Dendy, RN, Captain HMA/SEE, Fairlie, to Director of Miscellaneous Weapons, Admiralty, No. D.1802, 12 March 1945, ADM 1/17583; 'Hedgehog and Squid Probabilities,' J.R. Thompson, DMWD/20/61, 19 April 1945, ADM 1/17583; 'Hedgehog and Squid Probabilities (Addendum to DMWD/20/61),' J.R. Thompson, DMWD/20/61A, 16 May 1945, ADM 1/17583.

[312] Llewellyn-Jones, 'British Responses to the U-boat...,' p. 7.

[313] 'Effect of High Submerged Speed on U-boat Tactics,' W.H. McCrea, NORD, Report No. 20/45, 23 April 1945, ADM 219/225, p. 2.

McCrea pointed out that during the period of surface operations by U-boats, roughly one-third of contacts led to an attack, and about a third of these attacks resulted in a torpedo hit. Most of the failed approaches were due to interceptions by the convoy escorts. Some of the failures were due to the navigational problem of achieving a firing position, given the relatively limited engagement envelope of the torpedoes then in use. For the future, the situation would be different because a fast deep U-boat would be very difficult to intercept, unless there were revolutionary developments in escorts. Moreover, with pattern-running and homing torpedoes there was '...practically no problem of reaching a firing position other than merely getting within range.' In addition these torpedoes could be fired without use of the periscope and each salvo fired was expected to claim a greater number of casualties. In the future torpedoes were likely, McCrea thought, to have a much longer range, so that, together with improved underwater performance, future U-boats were not expected to have much difficulty in converting contacts into attacks.

McCrea noted that US submarines, '...admittedly against a moderately ineffective defence,' had been able to use their high surface speed to regain attacking positions, so that they could deliver an average of two (and sometimes as many as six) attacks during a single convoy engagement. The Type XXI, with its rapid re-loading torpedo system, ought to be able to achieve as much. Indeed, he gloomily predicted, if these boats could attack in packs, they might be able to create such confusion that there seemed little reason why, with a total load of 400 torpedoes, their attack might not annihilate a 100-ship convoy. McCrea thought this offered a challenge, for

> ...the U-boat pack of the future (say about 10 years hence) could be more dangerous than the typical pack of the present war by a factor that might be of the order 100. This is not to say that its achievements would be measured by such a factor, but the figure is some index of the very big advances required in A/S measure[s].

But, he went on to say, the

> ...primary objective of the pack would be rendered unnecessary if the U-boats could be informed of the position and movements of shipping from other sources than their own reconnaissance. If the enemy could maintain adequate air reconnaissance (or some system of radar relays) combined with adequate navigational aids, he might choose to dispense with the pack system. In certain circumstances he might thereby achieve a dispersal of our A/S forces and more immunity for his U-boats.[314]

At first sight McCrea's paper seems to offer a rather gloomy prognosis for the future, and was quite out of character with his numerous other analyses. But his paper, with

[314] 'Effect of High Submerged Speed on U-boat Tactics,' W.H. McCrea, NORD, Report No. 20/45, 23 April 1945, ADM 219/225, p. 2.

remarkable insight, captures the nature of the problems and neatly encapsulates the challenge to be faced by anti-submarine forces for the future. There is no doubt that the wartime Admiralty would have confronted the issue and focussed the necessary resources of manpower and technical development on seeking solutions. However, just as the threat became a reality, the war in Europe ended, and with it the resources rapidly began to diminish with the demobilization of many of the wartime experts. McCrea, for one, soon left the Admiralty. Nevertheless, it was clear to everyone that the Type XXI technology would set the future standard of submarine capability. It is not surprising, therefore, that the British (and the Americans) put a great deal of effort into extracting as much information as possible from their former enemies once the war was over.

Captain Roberts' Interrogation of German U-boat Officers

Barely a fortnight after the European war ended, Captain G.H. Roberts of WATU led an Allied team of experts on a week-long visit to the Continent to interrogate German U-boat officers. He was accompanied by Commander P.W. Gretton, an experienced Escort Group commander, Group Captain Gates and representatives from DNI, DNOR and the USN.[315] There were no surprises from the interrogations. Roberts' visit largely confirmed British assessments of German tactics and also revealed the enormous gulf between the two navies in their ability to co-ordinate all the operational, technical and training aspects of the campaign. The agenda for the visit, however, illuminates the main British concerns over future anti-submarine warfare. Roberts clearly wished to interrogate as many German officers as possible but was limited in his subjects by the poor state of communications, the general dispersal of personnel (many of them were PoW's in Russian hands) and the chaos following Germany's defeat. Nevertheless he was able to interview a number of key personnel, including Rear Admiral Godt, who had taken operational control of the U-boat arm after Dönitz became C-in-C of the German Navy. Other key witnesses were Commanders Hessler, Cremer and Schnee. The former, a successful U-boat commander before becoming Staff Officer Operations at the U-boat headquarters, had helped plan for the first Type XXI operations and clearly had a detailed, if somewhat uncritical, knowledge of their capability. Cremer and Schnee were also experienced U-boat commanders and had commanded the first two Type XXI U-boats, *U-2519* and *U-2511*. (A third veteran U-boat commander, Erich Topp, was appointed to *U-2513*.) Cremer's boat was, however,

[315] 'Life and Letters of Gilbert Howland Roberts,' Book 1, '11 October 1900 - 4 August 1945' [c. mid-60s], Captain G.H. Roberts RN, Papers, IWM 66/28/1, p. 144.

heavily damaged in an Allied air raid but Schnee, after a faltering start (due to serious technical defects), made one short operational sortie.[316]

Roberts concluded that the German plan was to continue the inshore campaign with the coastal Type XXIII, gradually replacing the Type VII schnorkel-fitted U-boats in this role, which had been a stop-gap solution. The Type XXI, itself a stop-gap until the Walter Type XXVI was available, was to re-establish ocean anti-convoy warfare.[317] Both Godt and Hessler affirmed that it was planned to resume U-boat pack operations in deep water with the Type XXI, although they admitted that '...the projected methods of attack in Packs by Type XXI had not yet been worked out...' in detail. Hessler, however, later mentioned that the

> ...final "Battle Instructions for Type XXI and Type XXIII U-boats" were compiled from the evaluation of extensive sea trials carried out in one boat of each type, commanded by two well-trained officers, *Korvettenkapitän* Topp and *Kapitänleutnant* Emmermann.[318]

Consequently, the Germans had planned to operate Type XXIs individually in ocean operations until their capabilities were fully understood. They might then be used in shallow waters, though this large U-boat presented a strong asdic target and would be difficult to bottom safely. Furthermore, being a more complicated boat, it would be less resistant to depth-charge attack. Overall, the Germans thought, Type XXI was better adapted to open ocean operations. It became clear during the interrogations that the Germans had not developed a coherent concept of operations for the Type XXI and this impression was reinforced by subsequent questioning of U-boat personnel which became available to DAUD and DASW by the end of June 1945.[319] There was much faith that the "new" technology would overcome operational problems, though for these to achieve their full operational capability would not be possible until their crews had gained experience. This would have taken time, which would have given the British the breathing space to hone their tactical counter-measures.

The Germans were pressed on their concepts for using these U-boats in ocean attacks. Ultimately, they wanted to use pack tactics after the crews had gained

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[316] Captain G.H. Roberts, RN, Western Approaches Tactical Unit, to C-in-C, WA, 30 May 1945, ADM 1/17561, *passim*; Erich Topp, Letter, 7 July 1997; Peter Cremer, *U333: The Story of a U-boat Ace*, tr. Lawrence Wilson (London: The Bodley Head, 1984), p. 202.
[317] The following narrative is based on the interrogations of Rear Admiral Godt, Commanders Cremer and Hessler, and Lieutenant Commander Mehl, in: Captain G.H. Roberts, 30 May 1945, ADM 1/17561.
[318] Hessler, *The U-boat War*, Vol. III, p. 86; '*Kampfanweisungen fur Typ XXIII* (Battle Instructions for Type XXIII),' M.G. Saunders (tr.), DNI, NID.24, Ref: TR/PG/28986/NID, 24 April 1946, Box 270, FDS, NHB.
[319] 'Summary of Statements made by German Naval and Technical Personnel,' NID 1/PW, Summary No. 133 for week ending 22 June 1945, 'P/W Summaries, 121-136' Vol. VII, NHB.

experience during solo operations. The intention was for pack tactics to be carried out submerged, which raised the tricky problem of communications, essential for co-ordinating the concentration of the pack and avoiding mutual interference during attacks. The Germans thought that the difficulties would have been overcome, perhaps by use of the new "burst" radio transmitter system.[320] Cremer was of the opinion that submerged pack attacks could be made by using the good hydrophones and *Niebelung* (Asdic) of the Type XXI, combined with the use of periscope observations either by day, or at night with a good moon. The great advantage conferred on the Type XXI by its high submerged speed was that it could close convoys from much wider angles than earlier boats, as Schnee remarked to Group Captain Gates. Closing at a speed of 10-11 knots was economical in battery usage, and left sufficient capacity for subsequent evasion. Once contact was made the Germans would soon have the option of firing from outside the screen using long-range torpedoes. The balance of opinion was that the final screen penetration would be made at silent speed, about 5 knots, with the submarine bow-on to the convoy, so that she would present the smallest asdic echo. Even at 8 or 9 knots the Type XXI was no noisier than a Type VII at 3 or 4 knots. Once through the screen, the Type XXI's speed and endurance would allow her to get under the convoy where, in relative safety, she could fire torpedoes from deep. The most difficult problem, once under the convoy, was to maintain station there. It was easy, Roberts deduced, for the U-boat to fail to appreciate an alteration of course by the convoy, though he did not press the questioning for fear of revealing that this was in the current British inventory of counter-measures against a U-boat sheltering under a convoy. The Type XXI's high speed and great manoeuvrability was best reserved for avoiding attacks by A/S vessels. However, Gates, drawing together the opinions of the other interrogators considered

> ...that, generally speaking, we had given...[the Germans] more credit than was their due. We were about 3 months ahead in anticipating the effects of the Type XXI U-boats and that we were inclined to give more credit than their tactical ability would really warrant.[321]

The potential threat posed by the Walter-boats, however, seemed altogether more formidable, and was at the forefront of Admiralty and Roberts' thinking. Roberts spent a fifth of his time in Germany specifically locating the positions where the Germans had scuttled the prototype Type XVII Walter-boats. He also questioned the German officers on the tactical use of the Type XXVI Walter-boats. These boats, Admiral Godt stated, were to have been large, ocean-going submarines, similar in size

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[320] This is discussed in more detail in Chapter 5.
[321] 'Bergen,' Gretton Papers, NMM(G).

to the Type XXI, though construction had not yet started. The Type XXVI was planned to be capable of sustaining 23 knots for 6 hours, using its Walter-turbine propulsion system, after which it would have expended all of its hydrogen-peroxide fuel. The high, but limited endurance, sprint speed of the Type XXVI could be used to gain bearing to get into a good firing position and to avoid being attacked. These U-boats were also equipped with a conventional diesel-battery system, though of much lower capacity than that fitted in the Type XXI and little better than that of the Type VII. During the interrogation Admiral Godt exposed his technical ignorance of the Type XVII's capabilities, which he confused with those of the much more ambitious Type XXVI design.[322]

Horton succinctly summarised the situation. "We must be prepared," he observed

> "...for a definite increase in underwater speed with a new type of self-contained submerged propulsion...and the U-boat virtually need never surface. But hand in hand with high underwater speed goes an increase in underwater noise. Hence, if the future U-boat decides to use its speed at an inopportune moment, it may well give away her presence at a considerable distance. It may, therefore, be deduced that if such high speed is to be available, it will be used mainly for withdrawal from being attacked by an escort vessel or withdrawal to safety after firing torpedoes. I believe that the actual method of attack in the future will still be slow, stealthy, and silent.
>
> "This new propulsion may also affect torpedo design, and we may find long-range fast torpedoes fired at convoys from outside the screen. Yet I believe that the skilled torpedoman will prefer to get to short range in order to obtain maximum hits. This again implies close range and stealthy infiltration of the screen by the U-boat.
>
> "New tactics for attacking the fast U-boat must be devised, new types of faster escort vessels, and new types of weapons are very early and pressing requirements."[323]

The Thrall of the Walter-Boat

At the end of February 1945 DNI reported on the German development of the small Type XVIIB and the large Type XXVI U-boats, both incorporating the Walter gas turbine propulsion unit for very high speed submerged. DNI's report confirmed that the Germans had completed at least three Type XVIIB and were building five more. DNI also thought that the Germans would start producing the Type XXVI shortly.[324] These boats potentially posed a dangerous threat and one that concerned the Admiralty. Perhaps the mesmerising quality of high underwater speeds and technological novelty overwhelmed the objective review of their serious operational limitations, particularly their poor endurance. Nevertheless, Roberts paid a great deal of attention to these

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322 See Appendix 7.
323 W.S. Chalmers, *Max Horton and the Western Approaches* (London: Hodder and Stoughton, 1954), p. 228.
324 Minute, [Commander] I.M.R. Campbell for Director of Naval Intelligence, 15 March 1945, ADM 116/5202; Minute, G.B.H. Fawkes for Admiral (Submarines), 27 April 1945, ADM 1/16384.

boats during his visit to Germany. When his report arrived in the Admiralty it was undoubtedly noted amongst the senior members of the Staff dealing with A/S matters. Roberts' assessment emphasized the lack of any coherent German doctrine for the use of the Walter boats, but this did little to ameliorate the Admiralty's concern over the ability of existing weapons to deal with this 25-knot submarine.[325] Prichard immediately wrote to the Captains of HMS *Osprey* and HMA/SEE, enclosing a paper on the "Use of Squid against the 25 Knot U-boat" and asking for comments as well as trials on the attack teachers. The problem, Prichard suggested, was a complex one, because the analysis would have to consider the '...efficiency of the asdic set and the manoeuvring qualities of the ship...' in order to arrive at an estimate of the effectiveness of the weapon. It was also necessary to consider the modifications already planned to the weapon and asdic gear, which would be forthcoming in about five years' time.

In his paper, Prichard proposed to deal with the problem, firstly, over the next five years and, then, for the longer term. Squid, he noted, had been designed to destroy '...a slow-moving U-boat whose maximum diving depth was about 800 ft.' Because of the high sink rate of the Squid bombs, it was unlikely that a U-boat, even at great depth, would be able to avoid the pattern by an alteration of course, unless he used speeds in excess of three knots, or had ample warning of the moment of firing by the A/S ship. Wartime experience suggested that conventional U-boats achieved neither of these criteria. Consequently, during the last months of the war, Squid-fitted ships were achieving a 60% kill rate, double that of Hedgehog and 12 times higher than depth-charges. However, against a submarine capable of up to 25 knots the probability of success would be '...wholly different....'[326] Prichard cited several reasons for this. In any deliberate hunt against a fast submarine, attacks tended to delivered from the stern of the submarine, as the trials with *Seraph* had shown. At this aspect, accurate asdic ranging on the target would be made more difficult by the interference caused by the submarine's wake. Errors would, therefore, be introduced in the calculation of the moment to fire, and this, in turn, would degrade the accuracy of the attack. It was also possible that the HE from the target would be so loud as to obliterate the echoes in the operator's headphones and on the asdic recorder, making it impossible to fire at all. Even if contact could be maintained, the submarine could make much greater use of the weapon's dead time, that is the time between the moment of firing and the arrival of

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[325] 'The Use of Squid against the 25 knot U-Boat,' Captain N.A. Prichard, DASW, to Captain HMS *Osprey* and Captain HMA/SEE, ASW 945/45, 2 July 1945, ADM 1/17591.
[326] 'The Use of Squid against the 25 knot U-Boat,' [Captain N.A. Prichard], DASW, [ASW 945/45], 30 June 1945, ADM 1/17591, p. 2.

the bombs at the preset target depth, to avoid damage from the pattern. The situation was equivalent to attacks with depth-charges against slow submersibles.

It might not be possible to set sufficient deflection on the Squid mounting to hit a submarine on a crossing course when it was taking avoiding action. The firing bearing would, therefore, have to be estimated by the ship's team. Similarly, in a counter-attack, when the submarine might be closing the A/S ship at high speed the accuracy of the attack could be compromised by the high dynamics. 'In fact,' Prichard concluded,

> the difficulties of attack with present asdic and Squid gear are so numerous that nothing other than a "snap" attack could reasonably be attempted against a U-boat travelling at 25 knots.[327]

At 25 knots, however, the HE from a submarine, Prichard thought, would be very loud, making it possible for the A/S ships to hold contact fairly easily, as least for a time. However, this presupposed that the asdic would function as a hydrophone at the high speeds necessary for the escorts to remain close to the target. This might be a particular problem if the submarine chose to evade at high speed and up sea. A/S ships might not be able to keep up and '...loss of contact might well be the rule....' Prichard observed that a new dome to house the asdic was being produced at the highest priority, which, he hoped, would allow asdics to be operated at 25-30 knots, by reducing effects of flow noise round the dome. In all this he was ignoring the possibility that, if the submarine were able to evade at great depth, then the HE from its propellers might be much reduced, as DNOR and ASWORG had noted in earlier analyses.[328] Beyond the next five years, Prichard hoped that certain modifications would improve the situation. Squid, as had been foreseen a year earlier, needed to be '...adapted...for use as an A/S gun.' In such a form the weapon would be used to fire salvoes of bombs '...with a fair degree of accuracy...', either in a counter-attack or in a series of firings to achieve a kill. But this could only be attained '...in conjunction with improvements to the asdic gear....' These improvements were the adoption of the asdic split-beam technique (which eliminated the need for the "cut-on" procedure) and PPI displays, which would allow a high speed contact to be held accurately. To hold contact, the asdic domes would have to be modified to allow operation '...in any seaway in which high speed is possible.' The asdic amplifiers, too, had to be modified '...to overcome

[327] 'The Use of Squid against the 25 knot U-Boat,' [Captain N.A. Prichard], DASW, [ASW 945/45], 30 June 1945, ADM 1/17591, p. 3.

[328] 'Surface Craft Tactical Countermeasures to Type XXI U-Boats,' Research Report No. 93, ASWORG/206 (LO)1380-45, 4 May 1945, ADM 1/17588.

the heavy masking of the echo by the HE of the target, thus enabling a succession of attacks to be delivered on a fast moving target.'[329]

In this paper, Prichard had not quite defined the ultimate requirement for this type of weapon: the capability to fire on any bearing and at a variable range. He did, however, think that a weapon of the A/S gun type held one major advantage over a homing torpedo, which could only hit or miss, and, therefore, was of little use in a counter-attack. Prichard hoped, too, that a submarine approaching a convoy at very high speed would produce so much noise that ample warning would be achieved, allowing the convoy to manoeuvre out of the U-boat's path. This tactic might be successful, he thought, since the U-boat itself would be deaf at these high speeds and would not appreciate the convoy's evasive turn until it slowed down to fire, when it might be too late. Prichard, however, was not taking into account the possibility mentioned elsewhere, that future submarines would be able to fire long-range torpedoes from well outside the detection range of escorts. At the time of writing the paper Prichard still anticipated that a partial answer to this problem would be deduced from the forthcoming trials with the captured Type XXI U-boats.

Over the next month both *Osprey* and the HMA/SEE wrote appreciations and carried out trials on the asdic attack tables to determine whether Squid would be able to cope with a submarine travelling at 20-25 knots. Their conclusion was that it would not. HMA/SEE considered the problem further in August but returned to the same conclusion. He also considered the relative merits of rocket-propelled and Squid-type weapons in dealing with these very fast submarines and concluded that the Squid-type seemed the more promising of the two. A few months later, in October and November 1945, Commander J. Grant, Commander (D), Londonderry, and HMA/SEE used the Londonderry Flotilla for trials against a high speed motor torpedo craft, simulating Walter-boats, to investigate the requirements for a future Squid-type weapon. These trials concluded that the current Squid and A/S gear were inadequate and what was needed was a weapon capable of firing at a variable range and over an increased arc of training. This idea would eventually be the basis for the "Limbo" A/S mortar Staff Requirement issued in the following year. Meanwhile, *Osprey* and HMA/SEE investigated the ability of a '...striking force of five 35-knot escorts with air co-operation' to chase a 25-knot submarine. Their reports concluded that:

> A/S vessels could maintain contact provided surface weather conditions allowed them their full speed, but [the escorts] would have difficulty in attacking. Aircraft co-

[329] 'The Use of Squid against the 25 knot U-Boat,' [Captain N.A. Prichard], DASW, [ASW 945/45], 30 June 1945, ADM 1/17591, pp. 4-5.

> operation with sono-buoys would help but [it was HMA/SEE's] view that sono-buoys would have to be super-sonic and directional.[330]

Osprey and Londonderry undertook only one investigation into attacks on a convoy by a single Type XXI U-boat, which had to be cleared out from under the convoy. The emphasis in the first few months after the German war ended was clearly on investigations to counter the potential threat of the Walter-boat. At the end of the war

> ...our Assault Teams entered Germany, and the secret of the German accomplishment was revealed. The importance of this discovery was appreciated at once and steps taken...to control the establishment where this research was being carried out and to hold the German personnel employed there.[331]

These activities were a closely guarded Anglo-American secret.[332] This interest was reflected in the extraordinary measures taken by both Britain and the US to secure specimens of the existing Walter-boats, the Type XVIIs *U-1406* and *U-1407*, whose locations were confirmed and reported by Captain Roberts in May 1945. These boat had been scuttled, contrary to the surrender terms at the end of the war. The British were so irritated by this action that the German officer responsible was tried and imprisoned. So important was this acquisition that the British delegation negotiating the division of the German fleet with the Russians in August 1945 were told that the hydrogen peroxide fuel (known as high test peroxide, or HTP) facilities, needed to support these boats, should not be discussed with the Russians. The British had raised *U-1407* in June, and at first intended to re-fit her in Kiel. But in mid-July, the Controller called a meeting to discuss the Admiralty's policy on the future of submarine design, taking into account the information then being discovered in Germany. Considering the high potential of the Walter propulsion system, the meeting decided that *U-1407* should be brought over to Britain along with the higher powered Type 18X Walter-turbine (after it had been bench tested in Germany), with the project to be supported by Professor Walter's technical team. So, in August, *U-1407* was hurriedly sealed up and taken under tow to Barrow-in-Furness, followed shortly by much of the German personnel and test plant from the *Walterwerke* in Kiel. (By this time the USN had transported *U-1406* to America).[333] As HMS *Meteorite*, *U-1407*, became the only running Walter-

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[330] 'Summary of DTASW's Investigation on A/S Warfare,' Annex C to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960, p. 4; 'Progress Report: Shipborne A/S Weapons,' TASW.038/46, [5 September 1946], ADM 1/20960, pp. 6-8.
[331] Minute, Engineer-in-Chief, 30 January 1946, ADM 1/27774.
[332] 'Monday, 7 May 1945, War Diary (Naval), 1-15 May 1945,' NHB.
[333] 'Search for three experimental U-boats, Type XVII, May 26th,' Appendix X to Captain G.H. Roberts, 30 May 1945, ADM 1/17561; Chris Madsen, *The Royal Navy and German Naval Disarmament, 1942-1947* (London: Frank Cass, 1998), p. 112-113, 124 n. 64 and 180.

powered submarine in 1949.[334] A Russian-built version of the Type XXVI was used for trials between 1955 and 1959 but, following an explosion during a submerged run, she was decommissioned. By then the British were successfully running HM Submarines *Explorer* and *Excalibur* both with improved HTP turbine designs.[335]

Planning U-boats Trials

In the autumn of 1944, while the trials with *Seraph* were still underway, Rear Admiral G.E. Creasy, Flag Officer (Submarines), proposed that some U-boats should be taken over at the German surrender for technical investigation and sea trials. Thus, naval trials were planned with Type VIIs *U-1105* (covered with rubber anti-asdic coating, "Albrecht") and *U-1171*, as well as Gnat and LuT torpedo firings. Radar trials of schnorkel detection were also planned for Coastal Command.[336] Most of these trials were completed by the end of 1945.[337] Both Creasy and DNI thought that trials with the Type XXI were of '...the greatest importance.'[338] At first sight the captured Type XXIs appeared impressive. They were large submarines with a sleek hull form, as had been noted by Captain Gilbert Roberts during his inspection of two Type XXIs during his visit to Germany in late May 1945. Captain Ashbourne, the Captain (S/M), Third Submarine Flotilla, conceded, that the Germans were '...streets ahead of [the British] ...in hull forms both as regards surface and dived speeds and deep diving depths.' But on closer inspection the '...general impression is one of admiral [sic] conception, but poor execution.' Overall, he added,

> ...these German submarines [were]...a queer mixture of very good and very bad points. The acute shortage of non-ferrous metals is evident everywhere. Wiring and switch gear copper is cut to the barest minimum, and there is continual trouble with seizure of steel valve spindles and similar gear. There is lavish use of synthetic rubber for silent and anti-shock mountings and even deck mats.[339]

In a post-war lecture A.J. Sims of DNC's department, doubted the claim that German submarines were structurally any better than the British types. Sims thought '...that there have been many exaggerated statements concerning the actual

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[334] 'Submarine Development,' DTASW, TASW.330/47, November 1947, ADM 1/27215, p. 4; 'HMS *Meteorite* Trials Report, 17 March to 30 April, 1949,' RNSM A1994/097.
[335] Jürgen Rohwer and Mikhail S. Monakov, *Stalin's Ocean-Going Fleet: Soviet Naval Strategy and Shipbuilding Programmes, 1935-1953* (London: Frank Cass, 2001), p. 205.
[336] 'Minutes of a Meeting held at Northways on 25 June 1945: Trials to be carried out in, and with, U-boats,' n.d., ADM 1/18557.
[337] Minute, G.B.H. Fawkes for Admiral (Submarines), 16 November 1945, ADM 116/5500.
[338] 'Type of German U-boats Required for Post War Experiments and Tests,' Admiral (Submarines), Northways, to Secretary of the Admiralty, 15 October 1944, ADM 1/16384.
[339] 'Third Submarine Flotilla Monthly General Letter – July 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), No. TSF.1230/3714, 8 August 1945, RNSM A1944/007.

achievements of the Germans. The type XXI class is a very good example....' The Germans hoped to achieve a collapse depth of 300 metres (975 feet) – slightly deeper than the British "A" class. In fact due to design weaknesses the boat could only go to 180 metres – and even at this depth '...local structural weaknesses were observed.' There was, he claimed, '...no evidence of abnormal structural strength of German hulls compared with our latest standards.' They had achieved greater diving depths not by improvements to the hull designs but by reducing the safety factor applied to the operating depths permitted.[340]

In July 1945, as America, Russia and Britain were haggling over the fate of the surrendered German fleet, and especially the remaining U-boats, Creasy was preparing to start the trials with a Type XXI, in advance of any formal allocation of U-boats to Britain. British planning was already well advanced and by mid July 1945, Admiral Creasy wanted to start the trials with a Type XXIII, *U-2326*, followed by the Type XXI, *U-2502*, after completion of her essential docking. Consideration was being given to experiments with the more radical design Walter-boats. The Admiralty approved the proposed trials programme at the end of August, even though manpower to crew captured U-boats was scarce. It is easy to see why the British were so keen to undertake trials with a Type XXI U-boat, since it was the only existing submarine capable of 15 knots submerged, as well as with the even faster Walter-boats. But it is more problematic to understand why they continued with the trials with the Type XXIII. Probably sheer habit and curiosity played their part and the organizations simply wanted to know whether their assessments during the autumn of 1944 had been accurate. Furthermore, it should be remembered that the British knew at the time that Type XXIII U-boats had made at least three cruises in British waters, and that none had been sunk.[341] And these trials were being planned while the war against Japan was still in progress, and while British forces were faced with the prospect of invading the Japanese homeland.

There was a desire to apply British experience to forthcoming operations in Japanese coastal waters. Interrogation of German PoW had established that details had been passed to the Japanese on U-boat designs, including the schnorkel, as well as new torpedoes, communications, radar, and GSR equipment.[342] The British did not rate the Japanese submarine force as highly as the defeated German U-boats, but it

[340] 'Submarine Development: Lecture given to Senior Officers' Technical Course on Tuesday 6 May 1947,' [A.J. Sims], RNSM A1990/083, pp. 4 and 9.
[341] 'Survey of A/U Operations...,' ADM 1/17653, p. 2; Hinsley, *et al*, *British Intelligence*, Vol. III, Part 2, p. 633.
[342] NID L.C. Report No. 999, H. Clanchy, DDNI(H), 16 June 1945, ADM 1/17653.

seemed logical that British developments should be measured against the technical capability of the Germans, even though it was assessed that the Japanese were unlikely to adopt all the German technology.[343] The Captain, HMS *Osprey*, Dunoon, had been kept informed. He had formed a new tactical unit at Christmas 1944 to deal with training for Far East operations.[344] Notwithstanding the effort being devoted to forecasting countermeasures to fast U-boats, the main operational focus remained on dealing with existing U-boat types. Pritchard, for example, made it clear that fast U-boats were to be expected in any future wars, and investigation of the tactics involved was to be prominent in the instruction of A/S specialist officers. But, for officers earmarked for operations against the Japanese the emphasis should be on inshore operations against conventional U-boats, and he

> ...considered that to give undue prominence to fast U-boats would not only be a waste of time but might lead to the employment of wrong tactics against the U-boats more likely to be encountered.[345]

In mid-June 1945, Captain Howard-Johnston, DAUD, instructed his staff to prepare a paper encapsulating the experience of inshore operations against German U-boats, which might have application to the Allied operations in coastal waters during the planned landings on the Japanese mainland.[346] Over the next few weeks, the British inshore A/S experience was drawn together during a series of weekly meetings, in co-operation with Captain Prichard. A joint draft paper was issued to other interested staff divisions on 5 August with comment requested within 10 days. They clearly had no knowledge of the imminence of the atomic bomb attacks, although the uncertainty over the effects these weapons would have may have not deterred Howard-Johnston and Pritchard. The paper was then to be sent to the Commander-in-Chief, East Indies, and to Admiral Nimitz. In the event, the Japanese surrendered after the dropping of the two atom bombs on 6 and 9 August 1945 and the joint paper was withdrawn.[347]

Prichard emphasized that the Admiralty's assessment of the future threat in Japanese waters was more focussed on an inshore campaign, rather than the start of ocean pack tactics. As a result information was being collated from PoW and captured German papers.[348] Against this background, the British were keen to pursue the trials

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[343] 'Submarine Warfare in the Pacific,' Secretary, Naval Board, NSS. 11270-53 Vol. 1 (Staff), 13 June 1945, Folder CNA 7-5-9, Vol. 11022, RG 24, NAC.
[344] Memoir, Mrs D. Coyne, [early 1990s], IWM 93/22/1, pp. 170-172 and 183.
[345] '*Osprey* Tactical Unit – Policy,' [Captain] N.A. Prichard, DASW, to The Captain, HMS *Osprey*, ASW1044/45, 25 July 1945, ADM 1/17591.
[346] 'Planning,' [C.D. Howard-Johnston], 12 June [1945], ADM 1/17653.
[347] DASW, to The Captain HMS *Osprey*, ASW/AUD.2018/45, 27 August 1945, ADM 1/17653.
[348] [Captain] N.A. Prichard, DASW, to The Captain, HMS *Osprey*, ASW1044/45, 30 July 1945, ADM 1/17591.

with the captured German Type XXIII, *U-2326*. In any case the British hand was forced by the series of defects with the Type XXIs which meant, DASW pointed out, that '...only the Type XXIII coastal U-boat, *U-2326*, was now available as a target.'[349] But *U-2326* also had her share of engine and schnorkel defects and it was not until July that she successfully completed her first dive, followed by First of Class trials at the end of August 1945 during which *U-2326* only achieved 9.7 knots submerged. This, Admiral Creasy pointed out, was below her '...reputed speed of 13 to 13½ knots...,' though her endurance was just under 2 hours.[350] A higher speed of just over 11 knots was eventually attained, but only at the expense of overloading (and damaging) the main motor.[351] Then under the control of Commander J. Grant, Commander (D) of the Londonderry Flotilla, in HMS *Fame*, she was used for a repeat of the earlier *Seraph* tactical serials. One key element of these trials was to determine which was the best weapon and attack procedure against the U-boat. The A/S ships were to stream Unifoxer continuously, which would allow any tactical disadvantage during high speed avoiding action by the submarine to be noted. During the trials the escorts were using the now routine combined 80°-80° echo and HE sweep. It had also been planned to investigate sonobuoy tracking of the Type XXIII but Grant reported that Coastal Command had cancelled these trials, which were, instead, to be completed against a British S-Class fast submarine.

In the opinion of Captain Lord Ashbourne, Captain, Third Submarine Flotilla, there was '...little to commend this cheap submarine.'[352] Nor, during the tactical trials, was naval opinion greatly improved. Grant reported that '...the Type XXIII U-boat does not appear to be of particularly robust construction nor can it dive to great depths or proceed at very high speed.'[353] Although, Captain W.J.W. Woods, who had relieved Ashbourne in September 1944, later admitted that *U-2326* had proved to be '...a small and handy submarine' that had advantages in both attack and evasion, it was difficult, he thought, for a Type XXIII to remain under a convoy as an evasive tactic. He also emphasized that, given her small size, *U-2326* offered a surprisingly good asdic target, which made it unwise to bottom to evade modern A/S vessels. However, the trials did

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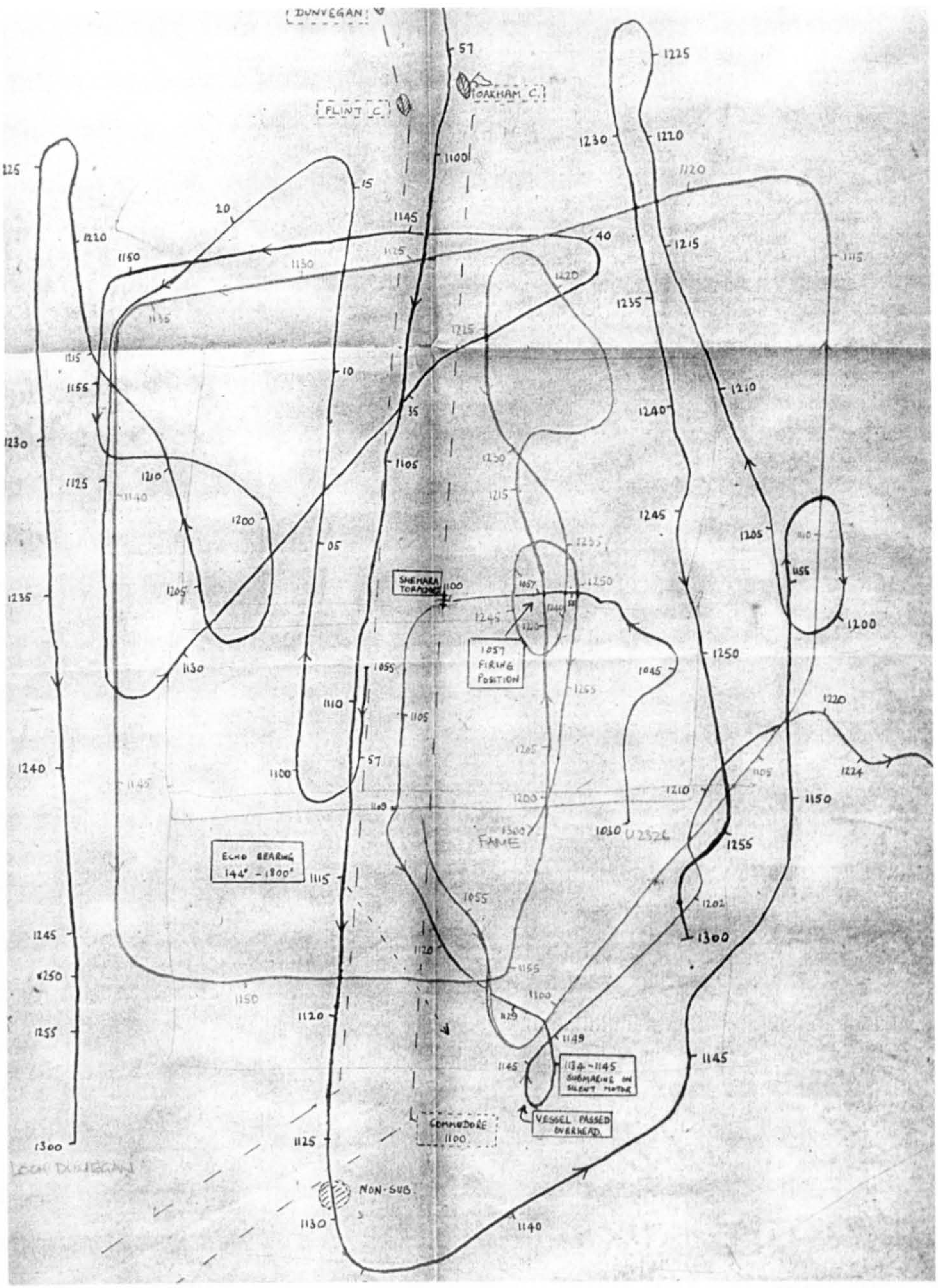
[349] 'Tactical Trials with Captured German U-boats,' DASW, [28] August 1945, ADM 1/18557.
[350] 'Appendix. Remarks on First of Class Trials and Deep Dive of *U-2326*,' Enclosure No. 3 to Admiral (Submarines') letter No. 1681/SM.3530 of 24 November, 1945. ADM 1/18557.
[351] 'First of Class Trials – Type XXI and Type XXIII U-boats,' Admiral (Submarines) to the Secretary of the Admiralty, No.1311/SM.3530, 7 September 1945, ADM 1/18328.
[352] 'Third Submarine Flotilla Monthly General Letter – July 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), No. TSF.1230/3714, 8 August 1945, RNSM A1944/007.
[353] 'Trials with Captured German U-boat – Type XXIII', Commander John Grant, Commander (D), Londonderry Flotilla, HMS Fame, D.14/21/1, 18 October 1945, ADM 1/18557, p. 2.

Plate 19: *U-2326* Track Chart

"Termex One" Convoy Exercise at Campbeltown, 14 October 1945, ADM 1/18557.



not go as well as these comments might suggest. *U-2326* operated at various speeds between 3 and 7½ knots, and occasionally bottomed, but as a result of peacetime safety rules, A/S ships were not to counter-attack during the tactical serials until five minutes after a ship in the convoy was "torpedoed", by which time *U-2326* would have cleared the immediate area unhindered.[354] Of course, as her Captain noted, the U-boat was not put under realistic pressure by the A/S ships, because they could not actually drop depth-charges, and consequently, neither the submarine nor the escorts behaved as they would in war. Although Grant conformed to tactical doctrine by ordering "Artichoke", "Square" and "Scabbard" searches, he failed to find *U-2326* because, as was normal for shallow water operations, interfering echoes and non-subs delayed the full implementation of each plan. The subsequent analysis of the serial also showed how untidy tactics could be in practice, when compared to the geometrical neatness of the tactical manual {*Plate 19*}.[355] This was well understood by experienced practitioners and helps to explain the emphasis placed on initiative by the wartime training organization. As the exercise played out, Grant was faced with an impossible dilemma: whether to try to cover the furthest extent of the U-boat's possible evasion, or to assume that she had bottomed near the position of original torpedo attack. He did not have the assets to cover both possibilities, and in any case did not have the strength to cast the wider search. And this against a U-boat capable of only 11 knots!

Type XXI Trials and Tribulations

As the summer of 1945 wore on, two factors started to have a great influence on future planning, one imagined and one real. Firstly, the Type XXIII trials, although reasonably successful in their own right, highlighted the shortfall in the submarine's performance when compared to its design speed. When the Type XXIs in British hands started to experience a series of major defects (some of them dangerous to submarine safety) and inspections revealed the poor build quality of these boats, doubts were fostered that the low performance of the Type XXIII would apply to the Type XXI. At the time it seemed reasonable to suppose that the Type XXI would be little faster than the existing British modified S-class submarines. There was no immediate threat to counter, for the Japanese were thought unlikely to be able to make use of such technology. The prime purpose of using the Type XXI boats was to establish the capability of existing A/S gear in dealing with a 15-knot target. If this speed could not be obtained, there was little advantage in persevering with the German boats and

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[354] 'Enclosure C to Commander (D), Londonderry Flotilla, HMS Flame's No: D.14/21/1 dated 18 October 1945,' ADM 1/18557.
[355] A similar point is made in Rodger, 'Image and Reality'.

having to cope with the endless defects. The British S-class would do. Furthermore, towards the end of the year the problems surrounding the Walter types became apparent. A meeting was held by DNC at Bath on 27 November 1945 where future submarine design was discussed.

It quickly became apparent that a fast submarine target for A/S detection and weapon development would not be available for some years and *U-1407* would not be available until late 1948 at the earliest. Other possibilities, such as new construction, were even more remote. The meeting concluded that a more extensively modified S-class submarine would be able to achieve speeds of up to 16 knots and, given the urgency of providing a fast target, plans for such a conversion should be pressed forward as soon as possible.[356] The problems with the Walter-boats were largely technical in nature. *U-1407*, considering her dilapidated state when she arrived in Britain, needed a substantial amount of work before she would be ready for sea trials. The Walter-turbines also needed further development, and there was the major task of supplying and storing adequate quantities of the hydrogen peroxide fuel (as well as specialised diesel fuel). All this entailed major expense.[357] This lack of a high-speed target was becoming critical if adequate testing was to be carried out of the new, improved A/S gear and weapons which would be ready at the beginning of the 1950s.

Once the trials with *U-2326* were completed, Admiral Creasy, Flag Officer (Submarines), reduced her to care and maintenance at Lisahally and, after a long delay, the Admiralty approved her loan to the French Navy in early 1946.[358] While the trials with *U-2326* were underway, it had been hoped to run the Type XXI, *U-2502*, but she proved to be an even bigger headache. She suffered a depressing series of defects, which required the U-boat to be docked, but while on passage to the shipyard at Cammell Lairds she suffered a main motor breakdown '...in a big way....' The repairs to *U-2502* would be a complicated and expensive operation and there was no guarantee that she would not break down again. All in all, she was becoming a project the British could ill afford. 'It has therefore been decided,' Ashbourne wryly commented, 'to return this model to Lisahally and draw another one.'[359] This boat, *U-3017*, was in

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[356] 'HMS *Scotsman*: Conversion to Fast A/S Target,' Section 27, DNC Department, October 1948, RNSM A1991/098.
[357] 'Ingolin (Hydrogen Peroxide). Underwater Propulsion Development,' 1945-1946, ADM 1/27774; 'HMS *Meteorite* Trials Report, 17 March to 30 April, 1949,' RNSM A1994/097.
[358] David J. Lees, 'Report of Operation "Thankful",' German Naval Group, World Ship Society, 1 December 1991.
[359] 'Third Submarine Flotilla Monthly General Letter – July 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), No. TSF.1230/3714, 8 August 1945, RNSM A1944/007.

little better state, but it was still a heavy blow when she suffered a battery explosion in August 1945 that caused extensive damage and put her out of commission.[360]

The explosion damaged *U-3017* and injured to one officer and seven ratings. The Board of Inquiry found that the accident was due to the abandonment of British procedures in favour of those used by the Germans. The Board suggested the German practices had caused a number of battery explosions in other Type XXIs, and had possibly led to their loss.[361] These rumours were supported by the interrogation of an experienced German Engineer Officer who recalled four battery explosions in Type XXIs. He stated that the main electrical cables ran in the bilges under the battery compartment, and that low insulation and the presence of bilge water caused arcing. With poor ventilation when the battery was freely exuding hydrogen (during charging), the likelihood of an explosion was high. This was a problem that also exercised the designers of the "Guppy" conversions of US Navy fleet submarines to achieve high underwater speed. At least one, USS *Cochino*, suffered a battery explosion and sank.[362] This dangerous design fault, along with other defects, meant, in Creasy's opinion, that

> ...before *U-3017* or any other Type XXI U-boat could be considered suitable for trials of a prolonged nature..., a complete and extensive refit and survey would be necessary.[363]

A despondent Ashbourne realized that they were virtually back where they started and it looked as though the working up of this type would be a protracted business. These engineering problems with the Type XXIs in British hands showed that if any of them were to be made fit for trials they would need substantial dockyard work. This would strain the existing British submarine refit facilities desperately needed for work on war-worn British submarines. These boats if they were to be more than 75% effective also needed to be fitted with the latest periscope radar equipment.[364]

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360 'First of Class Trials – Type XXI and Type XXIII U-boats,' Admiral (Submarines) to the Secretary of the Admiralty, No.1311/SM.3530, 7 September 1945, ADM 1/18328.

361 Enclosure to Admiral (Submarines) Letter No. 1415/SM.3577, 4 October 1945, covering the Report by Lieutenant J.S. Launders, DSO, DSC, RN, Commanding Officer of ex-German *U-3017*, 30 August 1945, ADM 1/18949; Board of Inquiry Report, HMS *Amphion* at Barrow-in-Furness, 3 September 1945, ADM 1/18949. No record of the loss of a Type XXI due to a battery explosion has been discovered.

362 Gary E. Weir, *Forged in War: The Naval-Industrial Complex and American Submarine Construction, 1940-1961* (Washington: Naval Historical Center, Department of the Navy, 1993), pp. 104 and 114.

363 'Board of Inquiry to Investigate the Explosion Onboard *U-3017* on 29 August 1945 (Captain (S/m), Third Submarine Flotilla's No. 6306/3739 of 13 July 1945),' G.E. Creasy, Rear Admiral (Submarines), 1415/SM.3577, 4 October 1945, ADM 1/18949.

364 'Meeting held by VCNS on 28 December, 1945, to consider the number of submarines that could be kept in service in the Post-War Fleet,' Head of Military Branch II, 5 February 1946, ADM 1/19301; 'Meeting held by Vice Controller at 1430 on 24 January 1946 to consider further

Moreover, as Creasy observed, the Germans had not succeeded in getting these submarines into an operational state. He also had in mind the preliminary results of the speed trials with the Type XXIII, *U-2326*, which had failed to achieve its design speed by over 2 knots, when he pessimistically questioned whether the Type XXIs would achieve a submerged speed much in excess of the converted "S" class.[365] This proved to be a crucial, though in hindsight, wrong assessment.[366] Still, at the time, Creasy's judgement made sense and he therefore recommended that the trials of a type XXI U-boat should be cancelled. He consoled himself, and the Admiralty with the knowledge that the US were intending to carry out trials with two Type XXIs, the results of which, it was hoped, would be shared with the British. In the meantime, a complete report of the type XXIII trials were forwarded to the USN.[367] On 14 October 1945, the same day as the tactical convoy exercise with *U-2326*, the Admiralty accepted Admiral Creasy's recommendation and cancelled the trials with the Type XXI's, *U-3017* and *U-2518*, remaining in British hands. These two U-boats were to receive "Care and Maintenance", though the Admiralty accepted, they would both require a substantial amount of work before they could be made ready for any future trials. There was, however, little prospect that they would ever be brought forward. It was against this background that the decision was taken to loan the Type XXI, *U-2518*, (along with a Type XXIII, *U-2326*) to France. Thus, until a British 15-knot underwater target was available, the British remained reliant on the results of the US Type XXI trials, further trials with the 12-knot *Seraph*-types, and on theoretical assessments.

The decision, sound though it seemed at the time, provoked considerable concern amongst many departments. The wide interest in the planned trials the Type XXI highlighted the importance attached to investigations with a submarine capable of speeds in the order of 15 knots, both to test existing A/S equipment and tactics, and also to provide data from which new weapons and tactics could be developed. The cancellation of the trials with the Type XXI was, therefore, a serious blow to these development programmes. Leon Solomon of DNOR suggested that the Americans should be asked to confirm their intention to continue with the trials, for if they too were to cancel it would leave both nations with a lack of information on fast submarines, until

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the number of Submarines that could be kept in the Post-War fleet,' M.023/46, M. Platt, Head of M. II, 18 February 1946, ADM 1/19301.

[365] 'First of Class Trials – Type XXI and Type XXIII U-boats,' Admiral (Submarines) to the Secretary of the Admiralty, No.1311/SM.3530, 7 September 1945, ADM 1/18328.

[366] 'Proposal to refit and re-commission *U-2518* on return by the French Navy,' [Captain] Ashbourne, DTASW, TASW.44/47, 7 February 1947, ADM 116/5500.

[367] 'First of Class Trials – Type XXI and Type XXIII U-boats,' Admiral (Submarines), No.1311/SM.3530, 7 September 1945, ADM 1/18328.

data was available from the captured Walter-boat, *U-1407*.[368] The Director of the Operations Division replied that he had ascertained, unofficially, from a submarine officer on the US Navy staff in London that the Type XXIs in America were being refitted, after which it appeared that the Americans planned to continue with sea trials.[369] The British decision to abandon the Type XXI trials was made just as the anti-submarine warfare divisions were undergoing a major reorganization. The streamlining of the A/S divisions, in particular, was to help focus attention on the review of A/S doctrine as will now be recounted.

[368] Minute, L. Solomon, DNOR, 1 November 1945, ADM 1/18328.
[369] Minute, Director of Operations Division, 2 November 1945, ADM 1/18328.

Chapter 5: Short-Term Problems, Long-Term Solutions, 1946-1947

New Organization and Old Timers at the Admiralty

First, some myths have to be disposed of. The Admiralty has been characterised as an organization where there was

> ...discomfort with new ideas, a preference for "wait and see", gradual acceptance of initiative if and when established by senior or political decision, much referral to committees, much consultation, much anxiety to involve every one with an interest.[370]

There is some truth in these assertions, and may reflect what the Admiralty eventually became, but during the period under consideration here, the Admiralty proved to be a very different animal. When Admiral of the Fleet A.B. Cunningham joined the Admiralty as First Sea Lord in October 1943, he was shocked by the number of departments and people who had to be consulted before decisions were possible. Cunningham had been used to a small operational staff in the Mediterranean, but he soon realized that the Admiralty actually a well lubricated organisation. By 1944 it had developed into a supple and creative agency, well able to meet the challenges of tactical and technical changes by the enemy, though to outsiders, like Cunningham, who were unused to the changes of pace brought about by the war, it treated most complex problems as matters of daily routine.[371] It was, unlike the War Office and Air Ministry, staffed by relatively few service officers, so delegation was commonplace.[372] Nevertheless, by the end of the war it had become a massive bureaucracy with parts of the organization spread across the country. The Naval Staff alone, consisted of 17 Divisions, compared to six in April 1939.[373] Work had been in hand for some time to rationalise this structure, and in particular to bring together many of the aspects of underwater warfare. As a result of the conclusions of the Phillips and, later, Middleton Committees, it had been decided to amalgamate the Torpedo and the Anti-Submarine Branches and this decision resulted in the formation of a single division of the Naval Staff whose "...prime concern...was the more effective integration of A/S training and weapon

[370] Moore, *The Royal Navy and Nuclear Weapons*, p. 19.
[371] Viscount Cunningham of Hyndhope, *A Sailor's Odyssey* (London: Hutchinson & Co., 1951), p. 577.
[372] N.A.M. Rodger, *The Admiralty* (Lavenham: T. Dalton, 1979), pp. 154-155.
[373] Minute, VCNS to First Sea Lord, 3 September 1945, ADM 1/17743.

development."[374] This new Division, responsible to Assistant Chief of Naval Staff (Warfare), subsumed the wartime DASW and DAUD, and elements of four other divisions. It was known as the Torpedo, Anti-Submarine and Mine Warfare Division (DTASW), and formed in September 1945. DTASW included a submarine qualified staff officer, though Flag Officer, Submarines, continued to provide detailed advice in his sphere of expertise.[375]

The first Director of the TASW Division was Captain Lord Ashbourne, who had specialized in submarines in 1925 and had served as Chief Staff Officer to Flag Officer, Submarines, between 1940 and 1942. He had also been the Captain of the Third Submarine Squadron during the planning of the trials with the captured German Type XXIII, *U-2326* in the autumn of 1945. The section of DTASW which is most important to the events being described here was the A/S section under Captain P.W. Burnett, DSO, DSC, and included Commander G.A.G Ormsby, DSO, DSC, and Lieutenant Commander J.P. Mosse, DSC. It took some six months for the vast Admiralty machine to slow down, and during that time the Staff Divisions still worked seven days a week.[376] Initially there was much to do and DTASW's responsibilities were legion.[377] Those which pertain to A/S warfare included policy, planning, tactics (of ships and aircraft), dispositions, staff requirements for new sensors and weapons, and training. He was also responsible for publications dealing with these topics, documenting their history, and attending various committees.

It was Burnett, as Assistant Director (A/S), with his team, who shouldered most of this burden. All of them were A/S specialists. Burnett had completed the long A/S course in 1933, when Howard-Johnston was a course officer, and at the time when A/S warfare was undergoing a major review which emphasized the problems of direct convoy defence (even though asdic was at last becoming effective), and the need for vigorous offensive measures.[378] The other two, Ormsby and Mosse had completed their courses in 1935 and 1936. In DTASW Burnett and Ormsby appear to have worked closely together on the staff papers. The former was noted as a man with "a

[374] Hackmann, *Seek & Strike*, p. 327; 'Report on Torpedo, Anti-Submarine, Ordnance and Electrical Branches by Rear Admiral H.C. Phillips,' March 1944, ADM 116/5692; 'The Middleton Steering Committee: Report on the Torpedo Anti-Submarine Branch,' Rear Admiral G.B. Middleton, CBE, Captain C.L. Robertson, John G. Lang, PAS(NP) and K. W. Matthews, Secretary, 22 December 1945, ADM 1/20207.
[375] 'Joint Paper on Sea and Air Aspects of Search and Convoy Defence,' P.W. Burnett, for DTASW, and F.J. Finnigan, Director of Operations, Sub-SAWC/II C.30414/D of Ops, [July 1946], Box 96, RG 313, NARA2, p. 10.
[376] Mosse, 'Half a Lifetime,' pp. 76-77.
[377] See Appendix 5.
[378] '[Battle of the Atlantic], Chapter III, Between the Wars,' [F. Barely and D.W. Waters], n.d., Box PT135, NHB.

fresh analytical approach to AS warfare."[379] Both men had passed out of Dartmouth in the top half dozen of their course. Mosse had been indoctrinated into Ultra during the war, while in a staff appointment. All three had had considerable experience in command at sea, where both Burnett and Ormsby had been Senior Officers of Escort Groups in the Atlantic, Arctic and Indian Oceans, and all three had been instrumental in the destruction of several U-boats.[380] Most of the early high-scoring U-boat killers had been non-A/S specialists or "salt horse" officers. Captain F.J. Walker had been something of the exception, though many of the regular A/S specialists had, perforce, been employed in the early stages in training and staff appointments, for at the beginning of the war there were only 60 A/S specialists available for appointment.[381] Burnett was one of the A/S specialists who was very successful when he went back to sea in 1943.[382] It was these men, under Ashbourne, all of whom had risen through merit and not through peacetime patronage, who set to work to produce a comprehensive review of anti-submarine warfare.

Policy Review of Methods of Attacking Submerged Submarines

Surprisingly, Ashbourne had not been party to the discussions over the cancellation of the Type XXI trials until November, when Solomon in DNOR included him on the distribution of the relevant files. Co-ordination at this time was not helped by considerable turmoil in the Naval and Scientific Staffs as the organization was streamlined.[383] Ashbourne caustically complained that he was acutely interested in the prospect of tactical trials with the Type XXI. 'The absence of a 15 knot target for A/S Trials,' he pointed out, 'will greatly handicap long-term development work on a weapon to counter 20 knot or faster U-boats.'[384] Ashbourne, partly from first hand experience of these boats, reluctantly accepted the situation and, in turn, added other departments to the file's distribution. DNC noted that a great deal of technical data was available on the Type XXI from German sources and this would be distributed in due course. He added that investigations were underway into a further increase to the underwater

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379 E. Maurice Chadwick, 'The Night the Gnats Bit,' in *Starshell*, Vol. VI, No. 7 (Fall 1997), pp. 11-12.
380 These included: Burnett – *U-744, U-989, U-1278, U-1279* (and probably two others); Ormsby – *U-198, U-386, U-406*; and Mosse – *U-354, U-394.*
381 'Asdic Trough the Ages,' Section 6, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB, p. 18.
382 Gretton to Howard-Johnston, 15 September 1980, 'H-J' File, Gretton Papers, MSS/93/008, NMM(G).
383 'Formation and Organisation of Naval Operational Research Department,' CE.60648/1946, 1941-1946, ADM 1/20113.
384 Minute, DTASW, 10 November 1945, ADM 1/18328; 'Proposal to refit and re-commission *U-2518...*,' ADM 116/5500.

speed of the converted S-Class, so that the control of submarines at these high speeds could be explored. Such plans were also supported by the Director of Scientific Research (DSR), and the Director of Torpedoes and Mining (DTM), who was pursuing weapons to counter the fast submarine, and who was firmly of the opinion that essential trials should be carried out with a British fast target.[385]

As soon as they were in post, Ashbourne's Anti-Submarine Section under Burnett began work on the policy and doctrine papers to guide A/S tactical and technical development during the immediate post-war years. They first surveyed the methods of attacking submerged submarines by surface vessels and aircraft. The paper, which was ready for Admiralty Board approval in March 1946, divided the future into two periods, separated by the year 1950.[386] For the near-term, up to 1950, A/S forces would be pitted against submarines of the capability of the German Type XXI and Type XXIII U-boats, which probably represented the best submerged performance currently available in an operational-type submarine. The anticipated performance of the various types was tabulated by Ashbourne.[387] The trials carried out by the Londonderry Flotilla with the Type XXIII, *U-2326*, in the autumn of 1945 had confirmed that against a submarine capable of submerged speeds up to 11-12 knots, the existing Squid and asdic gear were able '...to ensure a reasonable chance of success in an attack.'[388] The urgent requirement, then, was to establish whether existing ship A/S gear was capable of competing with submarines with a submerged speed of 15-18 knots. However, with no fast targets available, and the prospect of one a distant hope, Ashbourne had to settle for comprehensive sea trials with *Sceptre*, one of the modified 12-knot "S" Class submarines. He hoped it would be possible to extrapolate the results to be expected against a 15-knots submarine. *Sceptre*, which only seemed to be capable of 11 knots, exercised for two days with HM Ships *Fame* and *Hotspur* of the Londonderry Flotilla and the results merely confirmed those discovered with *Seraph* two years before that, '...the factor which limits a ship's success with a fast submarine [was] the skill of the attack team rather than the capabilities of the instruments.'[389] Nevertheless, training was seen as crucial to success and further trials were planned with the Portland

385 Minute, E.W. Pratt, for Director of Scientific Research, 18 December 1945, ADM 1/18328; Minute, R.C Boyle, for DTM, 4 January 1946, ADM 1/18328.
386 'The Development of A/S Warfare,' TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960, p. 1 and Annex B.
387 See Appendix 7.
388 'Policy Review of Methods of Attacking Submerged Submarines by Surface Vessels and (Appendix) by Aircraft', Annex B to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960, p. 1.
389 'Progress in Underwater Warfare, 1946,' DTASW, TASW.1453/46, CB04050(46), March 1947, ADM 239/420, p. 35.

Flotilla. The trial area was roughly uniform in depth at about 200 feet and free of wrecks – hardly operationally representative, but chosen for safety reasons.[390]

Lacking practical sea-based data, the DTASW paper concluded that Squid was the only in-service weapon adequate for attacking the modern submarine. The intention was to fit a Squid double mounting in specialized A/S types and a single weapon in other escorts, which, in the case of fleet destroyers, would entail mounting the weapon on the quarterdeck, so that the ships' normal anti-surface, and anti-aircraft armament would not have to be reduced. As for Hedgehog, it was, by now, considered to be an obsolescent weapon. The alternative had, for some time, been seen as the development of a ship-launched target seeking weapon, such as the passive acoustic homing torpedo "Bidder".[391] However, these weapons were limited by their own self-noise (and hence the speed of homing) as well as their reliance on the submarine making sufficient noise (and therefore travelling at speed). Against the latest fast submarines, "Bidder", in its present form, was too slow and too limited in its applications to be worth putting into production, but might prove to be the stepping-stone to a more effective weapon.[392] But in the face of these technical difficulties, there seemed to be some optimism, for the tactical investigations already carried out by *Osprey* in the early part of 1946 suggested that the basic plan of defending a slow convoy with a limited number of surface escorts remained '...unaltered and largely unalterable.'[393] The A/S School at Londonderry, however, found that it was possible to dispose a limited number of escorts in depth to give reasonable protection, at least against a 'single' submarine. More work had to be done to see if sea-air co-operation could be improved. Further work was to be included in the investigation programmes at the *Osprey* and Londonderry A/S Schools, and the Greenwich Tactical School.

Turning to the period beyond 1950, Ashbourne thought it likely that in the more distant future, the Royal Navy would have to be reckoned with a "true submarine" capable of a submerged speed of 25-knots and of diving to 1,500 feet. To improve the search rate of asdic an "all-round scanning" set was being developed. Initial detection would be made easier, if ship's self noise, particularly from its propellers, could be reduced. Searching would then be possible at higher speeds, and the A/S ship would be less vulnerable to anti-escort homing torpedoes. To increase the accuracy of weapon aiming against fast submarines, a new attack asdic, the Type 170, was well

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390 'Annual Report of TAS Schools, 1946,' UWD, CB4486, UW.05407/47, 24 October 1947, ADM 189/66, p. 37.
391 Minute, DASW, 2 April 1944, ADM 1/16495.
392 'Policy Review of Methods of Attacking Submerged Submarines...', ADM 1/20960, p. 2.
393 'Summary of DTASW's Investigation...,' ADM 1/20960.

advanced. This was based on the "split-beam" principle, which had been under development since 1941.[394] It allowed both azimuth and depth data to be measured instantaneously, thus avoiding the laborious "cut-on" procedure of the searchlight asdics. The resultant fire control solution could be applied to a relatively short-range "A/S Gun", the three-barrelled "Limbo" mortar, firing Squid-type projectiles all-round and at infinitely variable ranges from 300 to 1,000 yards which was also under development.[395] To extend the firing range further, it would be necessary to use a rocket projectile (as was being explored in America), due to weight considerations of the mounting.[396] However, it was difficult to find an accurate method controlling the propellant (and therefore the range), and it seemed that the "gun" method was likely to be the more promising of the two. Simultaneously, investigation was underway into a proximity doppler fuse for the weapon. Research was also in hand into a homing weapon, called "Zeta", which would benefit from data from the trials on the interim "Bidder" and "Dealer" weapons, which could be fired on the longer range data from the new asdics.[397] The testing and refining of these weapons was hampered by the lack of a 15-knot target.

The DTASW paper also considered the operation of A/S aircraft. In the near term, aircraft possessed four means of detecting submarines. Firstly, visual means were practically useless against fully submerged submarines, but in favourable weather conditions it was possible to spot periscopes, schnorkels and oil slicks, albeit at very short range. Secondly, radar could only detect a periscope or schnorkel at short range, and then only in calm weather. Thirdly, sonobuoys were able to detect fully submerged submarines, but ranges were highly dependent on submarine speed, while rough weather would render the equipment useless. Moreover, the size and weight of these sonobuoys meant that relatively few could be carried by an aircraft and when dropped they suffered poor serviceability. Current stocks were American types and were limited in numbers, until a British version was available. Fourthly, the Magnetic Anomaly Detector (MAD), was an American device able to detect a submarine at very short

394 Unmarked Paper of Detailed Comments on Problems at HMA/SEE, [August 1942], 'Papers Re Resignation from HMA/SEE, Fairlie in 1942,' KEYN 1, Correspondence: World War II and Radar, Acc. 23/667/669 (Keynes), Box 1, CCAC, KEYN; 'Example C: The Spit Beam Asdic,' Draft, n.d., CCAC, GOEV 3/1; 'Half-Yearly Scientific and Technical Progress Report,' HM Underwater Detection Establishment, Portland, 1946 (2), ADM 213/362.
395 'Progress Report: Shipborne A/S Weapons,' TASW.038/46, [5 September 1946], ADM 1/20960, pp. 6-9.
396 'Fourth Anti-Submarine Conference,' J.D. Price, Vice Chief of Naval Operations, OP 312F/rh A19 Serial 00296P31, 18 August 1949, File 8100.5, Vol. 3734, RG 24, NAC.
397 'Policy Review of Methods of Attacking Submerged Submarines...', ADM 1/20960, p. 3.

range but, although a version of this equipment had originally been developed in Britain in 1940, it was not used operationally by British aircraft.[398]

None of these methods offered a reliable method of detecting submerged submarines, so that aircraft remained constrained by chance detections, and operated on the optimistic hope that submarines might make occasional use of the surface. The primary aircraft A/S weapons were the wartime shallow-exploding depth-charge and the rocket projectile (RP), but these were useless against dived submarines. Although a new, variable-depth bomb was nearing the completion of its development, it was only effective if the position and depth of the target were accurately known at the moment of attack. "Dealer", a 15-knot passive homing torpedo, was in experimental production, but it was only effective against a submarine travelling at between 2-12 knots. Nor, in the longer term, was the outlook optimistic. It was hoped that directional passive sonobuoy types would help to mitigate the interfering noise from nearby convoys or co-operating A/S vessels, but they would still be critically dependent on the noise levels from the submarine and this could be reduced by technical advances, or by the submarines operating at slow speed. Active sonobuoys were also being considered, but these would be expensive, heavy and of short endurance. There were no immediate plans to adopt a Magnetic Anomaly Detector (MAD) and until some novel means of detecting submerged submarines from aircraft appeared the most promising developments were in the use of helicopters with a towed asdic. Although high priority was accorded to '...an air-launched anti-submarine target seeking weapon capable of carriage by Naval aircraft...' (known as "Zeta"), there remained many difficulties before an operational system was likely to appear.[399]

Developments in A/S Warfare

Following on from Ashbourne's review his A/S team embarked on a wider analysis of developments in A/S warfare in early spring 1946 which restated the problems but also looked forward to methods for their solution. The paper was passed round the Naval and Air Staff divisions in May before being sent to RN and RAF C-in-C's in September 1946. It was clear, the paper observed, that since June 1944 anti-submarine warfare had undergone considerable changes, first with the deployment of schnorkel-fitted U-boats, followed by the imminent introduction of fast submarines,

[398] 'A Review of the Methods of Attacking Submerged Submarines by Aircraft,' Appendix to Annex B to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960; 'Magnetic Submarine Detector (MAD),' Admiralty.134/1942, 1942, ADM 1/11741; P.M.S. Blackett, 'Evan James Williams. 1903-1945,' in *Obituary Notices of Fellows of The Royal Society*, 1945-1948, Vol. V (London: Morrison & Gibb for The Royal Society, 1945-1948), p. 396.
[399] 'A Review of the Methods of Attacking Submerged Submarines by Aircraft,' ADM 1/20960.

such as the battery-powered Type XXI and the more exotic Walter-powered, very fast Type XXVI. The submersible was successfully countered and stalemate had been reached against their schnorkel-fitted cousins as the war ended. A/S warfare was now presented with a threat that was rapidly progressing towards the "true submarine", which would not rely on any surface exposure.[400] Ashbourne and his team formalised these developments in two phases: the "Short-Term Problem" up to 1950; and the "Long-Term Problem" after 1950.[401]

The short-term counter-measures had to be developed against the 15-knot, schnorkel-fitted submarine, equivalent to the German Type XXIs. It was Ashbourne's hope was that it would be possible, in line with current Admiralty policy, to rely on existing gear with no major modifications, until completely new and much improved equipment became available after 1950, when the long-term problem of the Walter-boats would have to be countered. The outlook for aircraft, as has been noted, was less optimistic. The focus in the short-term was on tactical development and training of escort forces. Beyond 1950, the threat was more challenging and the emphasis would be on basic research to support the formulation of new ship and aircraft equipment requirements. The strength of these future submarine types, based on the German design for the Type XXVI, was their very high underwater speed, which might allow them to penetrate the A/S screen and get into a firing position, even if detected. They would also be able to outpace surface escorts under most circumstances, but their endurance at high speed was ultimately limited by the quantity of HTP fuel carried and the submarines left an observable trail at depths less than 60 feet. Their maximum operating depth on Walter propulsion was also limited. Future British designs for HTP submarines were intended to overcome the worst of these shortcomings. In the more distant future, Ashbourne conceived of a "true" submarine powered by atomic energy and at this point,

> The submarine of the future, then, can be expected to remain submerged continuously, using Schnorkel for short periods. It is probable, however, that they will sacrifice their surface performance entirely. It will be capable of high speed and endurance submerged and of detecting any transmissions made by the enemy. These submarines will attack with greatly improved weapons in close tactical packs assisted by accurate instruments. Finally they will be difficult to detect by echo, noise or magnetic field and they will be difficult to destroy due to their high submerged speed.[402]

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[400] For the contemporary submarine nomenclatures see Appendix 9.
[401] 'The Development of A/S Warfare,' ADM 1/20960, p. 2.
[402] 'Development of the Submarine,' Annex A to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960, p. 6.

Overall tactical development would have to take note of surface vessel and aircraft (both RN and RAF) requirements and was to progress through three stages, starting with theoretical studies, followed by simulations (using shore-side training equipment) to better understand the dynamics of proposed tactics. However, conclusions derived from these investigations would still be tentative and unreliable, until they were confirmed by sea trials against a fast target. Creating the opportunities for "realistic" sea trials, as always in peacetime, was to prove problematic. Firstly, there were no major exercises planned for 1946. Secondly, there would be no high-speed submarines available until late 1947, when the extensively modified HMS *Scotsman* (designed to achieve 16 knots) and the captured *U-1407*, would be ready for trials as HMS *Meteorite* (and capable of 17-19½ knots). It would not be until the early 1950s that British designed 25-knot HTP submarines and new 21-knot conventional diesel-electric submarines would be available. In the meantime the British would have to rely on exercises with the existing 12-knot "S"-class conversions, though these remained ill-suited for tactical work.[403] Peacetime safety rules, too, would limit realism so precluding the recreation of wartime "blood and guts" testing. Tactical solutions would never become fixed, for they were bound to be in a constant state of flux because of the interrelated advances in, on the one hand, submarine technology and operational methods, and on the other hand, developments in A/S countermeasures and tactics. Ashbourne emphasized that the conclusions from these investigations would '...be guess-work based on the tentative results of other investigations....' It was vital, he thought, that all the departments involved in these investigations should pool their information.[404]

As a fall-back, it was hoped that data would be gained from the US trials with two captured Type XXIs, *U-2513* and *U-3008*. These were in the hands of a combination of naval and civilian organizations who started sea tests only after a substantial period of docking for repairs (for which the Americans had greater capacity). Even then, the US trials proceeded at a pedestrian pace, with no tactical data emerging for some two years. Initially *U-2513* appears to have been used for sea trials, which showed that she was capable of maintaining 17 knots submerged for one hour. During the following year the U-boats only achieved a maximum speed of 15-15½ knots, and also revealed a number of defects in the Type XXI design.[405] These results, however, did not begin to

[403] 'Progress in Tactics, 1948,' ADM 239/144, p. 24.
[404] 'The Development of A/S Warfare,' ADM 1/20960, p. 3.
[405] 'Submerged Performance Tests on German Type XXI Submarines', William E. Schevill and Allyn C, Vine, Woods Hole Oceanographic Institution, 17 March 1947, File 3, Submarine/Undersea Warfare Division, Series III, Box 12, OA, NHC; 'Special Submarine Group

filter through to the British until the spring of 1947 in a summary produced by Commander R.G.C. Haines, the Staff Anti-Submarine Officer on the British Admiralty Delegation in Washington. It was hoped that a complete report might be available at a later date. The letter from Haines summarised a report from the American Woods Hole Oceanographic Institution, which had carried out technical performance tests with two Type XXIs. It was the lower maximum speed of 15-15½ knots that were passed to the Admiralty. The British staff in Washington hoped to send the full US report at a later date.[406] The Americans were hardly better informed, for as late as spring 1948, one American submarine squadron commander complained that there was insufficient data on the Type XXI '...upon which to base even a preliminary analysis of its full potentialities or weaknesses.'[407]

No documentary evidence was discovered which described the German plans for operation of the Type XXVI Walter-boat, so the Admiralty constructed its own tactical concept based on their own earlier operational and technical analysis, and the results of interrogations of German U-boat officers. Ashbourne was, however, in possession of a captured German document which described their plans for operation of the Type XXI.[408] It is not entirely clear why Ashbourne chose to use a précis of this paper as a template, given the more balanced analyses produced by DNOR, and others, during the war. Perhaps, because it came from an enemy who had kept A/S forces engaged for the whole of the war and required considerable effort to defeat, the threat of the Type XXI (which would now be in Russian hands) was given greater *gravitas* by citing the paper. The German paper contains many contradictions. It is also vague on many of the important issues, such as how convoys were to be located and how they could be attacked using Type XXIs in packs. Much was made of the greater underwater performance of these U-boats, especially in their ability to close targets by underwater travel from considerable distances, even though this might consume 80% of the battery power. This seems rather profligate, compared with the views of one ex-Type XXI captain, Erich Topp, who compiled the "Battle Instructions for the Type XXI and Type XXIII U-boats", and thought that battery capacity ought to be maintained at a minimum

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– Prospective Operations Schedule (Revised),' W. R. Laughton, The Commander Special Submarine Group, FC5-2/S8, 1 March 1946, File 1, Submarine/Undersea Warfare Division, Series III, Box 12, OA, NHC.

[406] 'Submerged Performance Tests on Type XXI U-Boats', Staff Officer (Anti-Submarine) to Director of Torpedo, Anti-Submarine and Mine Warfare, Admiralty, A/S 230-1, 14 April 1947, RNSM A1991/076.

[407] 'Proposed Evaluation of Present Guppy Submarine Conversion and Equipment,' L.R. Daspit, Commander Submarine Squadron Four, to Commander Submarine Force, US Atlantic Fleet, FC5-4/S1, 24 March 1948, Box 98, RG 313, NARA2.

[408] See Appendices 5 and 8.

level of 60-70%, unless in an emergency.[409] Such problems would be overcome if the submarine operated in focal areas, where shipping targets would be more plentiful, but where A/S forces would also be stronger.

The Germans considered that the overall defensive fighting power of the Type XXI was still weak, for the paper – echoing Dönitz' long-held philosophy – emphasized that the key to success was to remain unobserved before an attack so that the enemy would not take evasive action. Although the Type XXI had a much improved acoustic suite, greater emphasis was placed on the use of the periscope, which would inevitably restrict attacks largely to daylight hours. The Germans realized that attacking in packs was the most effective method of achieving substantial numbers of sinkings. However, it was apparent that the Type XXI was not well-suited to working tactically in close company with other boats. (This seemed to contradict some of the views expressed in Roberts' interrogations.) To compensate, the Type XXI could fire a larger salvo size of six LuT torpedoes and, with its rapid reloading system, could fire a second salvo five minutes later, and a third salvo after another 20 minutes. The recommended tactics for the attack were for a submerged approach to a convoy from forward of the beam. The screen would be penetrated at slow speed, either deep or at periscope depth, and then to fire salvoes of LuT torpedoes in rapid succession. The Germans calculated that there was a '...theoretical possibility of 95 to 99 per cent hits in an average convoy....'[410] After firing the Type XXI would dive under the convoy to reload, where the "Nibelung" asdic set and "Balkon" hydrophones were used to detect any alterations in the course of the convoy and, via a specially designed plotting-table, to allow further torpedoes to be fired from deep. After the third salvo the U-boat was supposed to remain deep under the convoy for a couple of hours and then escape at slow speed. This was not so easy as it seemed.[411]

Had the enemy been able to employ these submarines in the manner proposed, Ashbourne concluded, they would have been able to defeat the most effective British counter-measures and, since the Type XXI did not need to use the surface, except to schnorkel for short periods, aircraft would be virtually powerless to sink them while in transit, except on rare occasions. The Type XXI's weakness, was reconnaissance, so support by aircraft would be especially valuable in locating targets. An advantage was the use of the "Squash" or "Kurier", pulsed radio system, which allowed short, formatted messages to be cleared in less than one-half of a second. Existing ship-

[409] Erich Topp, Letter, 17 August 1997.
[410] Hessler, *The U-boat War*, Vol. III, p. 86.
[411] 'Development of the Submarine,' ADM 1/20960, p. 2.

borne D/F equipment could not exploit these signals, though this might be possible from shore stations within the next few years. It had been assessed that had the Germans possessed this system during 1943 that convoy losses might have increased by 30-50%.[412] In summary, Ashbourne wrote:

> The Type XXI has therefore neutralised air, shore and shipborne radar and D/F, but this type can still, with patience, be destroyed after detection by asdics. However, the power of asdics to prevent an attack is probably diminished. The larger salvo, rapid reloading gear and ability to keep station under the convoy, enormously increases the damage that can be done by any U-boat that penetrates the screen. The price of these advantages is the inability to concentrate and intercept convoys or to carry out effective pack tactics.[413]

There were chinks in the Type XXI's armour, but it would have posed a serious threat, and one that was in Russian hands if they were capable of converting the potential of this German technology into an effective weapon.

Assessments of the Russian Threat

During the Second World War the submarine threat had been obvious and immediate and had a direct impact on the direction of A/S development. That had not always been so in the interwar period, which '...was initially driven by a general awareness of the potential threat posed by submarines.'[414] In the same way, after the Second World War A/S measures were directed towards countering a generic threat imprinted on the Naval Staff's consciousness by six years of war experience, and because a Russian submarine threat against our trade or military operations was largely discounted in 1945.[415] Of course, account was taken of Russia as the only possible enemy, assuming that there would not be a resurgence of the threat from Germany. In spring 1946, the JIC assessed that Russia possessed

> ...about 210 submarines, including 10 ex-German. She takes a great interest in submarine warfare and in this particular arm of the Naval Service she has shown herself to be more proficient than in any other. She is, however, still inexperienced in attack tactics. So far as the building of submarines is concerned, Soviet Russia has already carried out one large programme with success. German assistance and methods, particularly in connection with pre-fabricated [Type XXIs and the like]

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[412] 'Notes on the "Kurier" System,' Enclosure (A), in, ' "Kurier" System of U-boat Communication,' 7 July 1945, Report No. 187-45, NavTecMisEu, Series III, Letter Reports #180-45 thru #205-45, Box 14, OA, NHC; 'On the Value of Squash in Pack Attacks,' [Leon Solomon], DNOR, OIC/SI1254, [19 March 1945], ADM 223/261.
[413] 'Development of the Submarine,' ADM 1/20960, p. 3.
[414] Franklin, *Britain's Anti-Submarine Capability*, p. 190.
[415] 'Operation "Unthinkable", Report by the Joint Planning Staff,' G. Grantham, G.S. Thompson, W.L. Dawson, Offices of the War Cabinet, Final, 22 May 1945, CAB 120/691.

> submarines, would enable her to construct a formidable Submarine Force in a comparatively short time.[416]

These assessments were reflected in the departmental calculations. Numbers alone, however, did not tell the story. Many of these boats were obsolete submersibles and most of the Russian ocean-going submarines were similar to the wartime German Type VII but without the schnorkel. The Russians had captured the plans of the later German Type XXIs and the Type XXVI Walter-boats, though it was thought unlikely that they could produce a home-grown version of this latter type until 1949 at the earliest. (It was not known until recently that the Russians used their three allocated Type XXI boats for trials until 1958, though the remaining Type XXIs which they captured in varying states of completion were all scrapped or scuttled by early 1948.)

In late 1946, NID assessed that:

> ...The Russians are far from being a nation of seamen, and this weakness is reflected in the operation of their submarines, however technically good these boats may be. Their attack technique is amateurish to a degree.... The submarines themselves are probably capable of carrying heavy armament a long way with reliability, but are by no means certain of hitting the target when they get there. Unless their evasive tactics have been much improved in the last year or so, they would stand little chance against our escort groups, and we have no information that attack-training has been carried out by them to any degree. This particularly applies to the large Russian submarines.[417]

This was a common theme for most of the immediate post-war period. Similar assessments appear in many of the Joint Intelligence Committee papers. For example the JIC did not believe

> ...that by 1957...[the Russians] will think themselves capable of co-ordinated pack attacks on escorted convoys; we consider that their methods are far more likely to be comparable to those used by the Germans in World War I; but they may hope that such devices as homing torpedoes will at least partially offset their tactical shortcomings.[418]

When DNI circulated its paper in October 1947 on "Russian Naval Tactics" round the Naval Staff, DCNS '...directed that an argument was to be developed as to the number of escort vessels we would require to meet this threat....'[419] The detail of this debate is not covered here, but the way in which these vessels were to be used is. No very great opinion was entertained of the Russian submarine operational capability, which was drawn together from the experiences of British and American liaison officers

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[416] 'Russia's Strategic Interests and Intentions,' Report by the Joint Intelligence Sub-Committee, JIC(46)1(0) Final (Revise), 1 March 1946, CAB 81/132.
[417] 'Russian Naval Tactics,' NID/16, 10 October 1946, ADM 1/20030.
[418] 'Scale and Nature of Attack against Sea Communications,' Joint Intelligence Committee, JIC(48)69(0)Final, 11 August 1948, CAB 158/4.
[419] Minute, Philip Currey, for DTSD, 29 April 1947, ADM 1/20030.

during the war, and information from the interrogation of German prisoners who had operated against the Russians. Captain Mackenzie, who made at least one war patrol in a Soviet submarine, later echoed the general impression, that since '...their A/S training is so backward is it not likely that their submarine tactics, particularly in attacks may be backward also?' His belief was that Russian submarine Commanding Officers' attacks were, at best, amateurish.[420] These views, the Historical Section later pointed out, had to be considered in the context of the difficult environmental conditions in which many Russian submarines had operated.[421]

Within the Admiralty, then, there seems to have been no direct pressure from an impending threat to drive A/S development, because the Russian threat was not yet well developed and would not be so until, say, 1955-60.[422] There was, as the Chiefs of Staff noted in May 1947, a need for a state of preparedness.[423] The wise counsel of staff officers, like Ashbourne and Burnett, was that unless work was done now and the issue kept in the forefront of the naval agenda, it would be too late to improvise counters to the fast submarine, when the Russians finally realized their potential. Over the next two years the Admiralty repeatedly asked the JIC to assess

> ...the capabilities and intention of the Russians and to forecast the probable scale and nature of attack in various possible theatres of war both in the near future and in some years ahead.

The appreciations were, generally, accurate in terms of actual strength of the Russian forces, but, the Admiralty were concerned that the JIC '...tended to exaggerate Russian potentialities.' This was serious, because, the Admiralty pointed out

> ...not only our present plans but also the future disposition of forces and the build up of military strength depends so greatly on what we estimate to be the Russian plans....[424]

Financial considerations would heavily influence the outcome of these deliberations, but at least a start was being made on the development of the doctrine for how these forces were to be operated. These implicitly assumed the ultimate state of British strength which could be achieved some years into another World War. These were the

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420 'Eleventh TAS Liaison Meeting: Minutes,' Part 13, 'Paper I – Review of Soviet Naval and Air Forces and their TAS Roles; Paper II – Soviet Underwater Weapons: Discussion,' 9-11 September 1952, ADM 189/235, pp. 152-157.
421 'Russian Submarines in the Second World War: An Estimate of their Efficiency (Reference: NATO (Secret) ID 0940/1 of 4 January 1955),' Historical Section, Admiralty, Box PT135, NHB.
422 'Soviet Interests, Intentions and Capabilities – General,' Report by the Joint Intelligence Sub-Committee, JIC(47)7(Final), 6 August 1947, CAB 158/1.
423 'The Overall Strategic Plan, May 1947 (DO(47)44 (Also COS(47)102(0)) (Retained – Cab Off)),' Appendix 7, in, J. Lewis, *Changing Direction: British Military Planning for Post-war Strategic Defence, 1942-1947* (London: The Sherwood Press, 1988), p. 372.
424 'Appreciation of Russian Intentions: Memorandum by the First Sea Lord,' Fraser [?], COS(49)161, 5 May 1949, DEFE 5/14.

conditions which officers, like Ashbourne and Burnett had been accustomed to for much of their seagoing wartime experience. Compromises would have to be made at the beginning of a future war, as had been the case at the start of the Second World War.

The First Tranche of Doctrine Papers

The post-war continuation of formed escort groups, the restructuring of the A/S Branch, and the maintenance of a large reserve of trained men for future wartime A/S operations were all seen as vital if the lessons of the war were not to be squandered. Ashbourne was determined that advanced operational training would be enhanced by the temporary continuation of a Joint A/S School at Londonderry.[425] This organisation was, eventually, formalized by the creation of the permanent Joint Anti-Submarine School (JASS). When the general issue of post-war training was being discussed in the Admiralty, the Director of Naval Air Warfare voice a common concern that

> ...in spite of all that has been done and is being said to the contrary, there remains a very grave danger of our sliding back once more in the coming "peace" into errors in Naval training similar to those of the last one. The temptation to concentrate on the more amusing and spectacular attack on the Fleet rather than the dull and difficult (but much more important) defence of trade is desperately strong.[426]

Captain G. French, RN, Deputy Director of Plans, went further when he observed that:

> ...the root of this matter is a question of outlook and of the importance... attached to the adequacy of our A/S training and of trade protection exercises. ...It is improbable that these will be given full weight unless there is a sufficiently powerful body of thought in the Admiralty organisation to insist upon it.[427]

Ashbourne agreed and proposed the establishment of a Joint Sea/Air Warfare Committee with both Royal Navy and RAF membership and chaired at the Vice Chief of the Naval and Air Staff level. The Committee, and eventually its sub-committees, would hammer out joint policy on all matters connected with A/S warfare and make policy recommendations to the Board of Admiralty and Air Council. This was to be done via the normal working of the relevant staffs of the Admiralty and Air Ministry. At their first meeting in May 1946 the committee discussed Ashbourne's paper on the implications of the schnorkel-fitted, fast U-boat. Thereafter a steady stream of papers were presented to the SAWC for approval. Furthermore, the Admiralty set up a series

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425 Minute, Captain Lord Ashbourne, DTASW, TASW.214/[45], 18 October 1945, ADM 116/5853.
426 Minute, DNAW, 25 July 1946, ADM 1/20045.
427 Minute by D of P, 26 August 1945, PRO: ADM 1/20045.

of "TAS Liaison Meetings" at which often 250 officers of the A/S community were present, and including representatives from the Commonwealth and the USA.[428]

The first meeting of the SAWC's Tactical and Training Sub-Committee on 7 May 1946, was chaired by Rear Admiral R.D. Oliver. The committee spent some time discussing the problems laid out in DTASW's paper on "The Development of A/S Warfare". It was agreed that solutions should be developed, in the first place, by the directorates responsible in the relevant areas, incorporating advice from the operational research departments where appropriate. Thus surface search and escort, air search and patrol related to trade defence were to be jointly examined by DTASW for the Admiralty and the Director of Operations (D of Ops) for the Air Ministry. Once these directorates had drafted the joint paper it would then be considered by the Sub-Committee. So, during the later part of the spring of 1946 DTASW and D of Ops worked together to produce a "Joint Paper on Sea and Air Aspects of Search and Convoy Defence".[429] This was followed by a complementary "Joint Paper on Sea and Air Aspects of Fleet Defence against Submarines", which was drafted under the leadership of Captain G. Willoughby, the Admiralty's Director of Air Warfare (DAW), though he, too, consulted with other Admiralty and Air Ministry directorates.[430] Deputy Director of Operations (Maritime) (DDOps(M)), Group Captain V.C. Darling, as Burnett's opposite number seems to have had a hand in the drafting, though there is no doubt that DTASW provided the lead for both papers.[431]

There was, of course, no specific and immediate threat from a maritime power possessing submarines, similar to the German fast Type XXI U-boat. The only potential enemy, Russian, did not yet possess such a submarine fleet. Thus the counter-measures proposed were pitted against an amalgam of the threat that had been developed by the Germans towards the end of the Second World War, together with improvements that might be assumed from German mistakes.[432] The two papers were, therefore, based on countering a generic threat. Thus it is not surprising that the solutions proposed in the two papers were essentially similar. Indeed, many of the paragraphs are directly transposed from one paper to the other. However, the papers

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[428] 'Third A/S Tactical Liaison Meeting held in HMS *Vernon* on 1st and 2nd May 1947,' A.198/3/47, 17 May 1947, distributed by Op-32-F-45, n.d., Box 102, RG 313, NARA2.
[429] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2.
[430] 'Minutes of the 1st Meeting of the Tactical and Training Sub-Committee and the 1st Meeting of the Technical Investigation Sub-Committee...,' Cdr G.R. Carver and W/Cdr J.L. Crosbie, Sub-SAWC/II/2/46 and Sub-SAWC/III/2/46, 13 May 1946, AIR 15/786.
[431] Minute, Group Captain V.C. Darling, RAF, DDOps(M), 30 September 1946, AIR 2/5950.
[432] 'German U-boat Strategy in the War,' Appendix XVIII, to 'Some Weaknesses in German Strategy and Organisation, 1933-1945,' Report by the Joint Intelligence Sub-Committee, JIC(46)33(Final), 20 October 1946, NHB.

differ in two important aspects. Firstly, the "Fleet Defence" paper assumes that a naval force would proceed at 15 knots or more.[433] If the naval force were steaming at a lower speed, then the principles established in the paper on convoy defence were to apply. Secondly, the paper on "Search and Convoy Defence" also covers the use of anti-submarine forces for offensive search operations. These forces are not mentioned in the paper on "Fleet Defence". The significance of this exclusion will become apparent shortly.

The drafting of the papers went on throughout the summer of 1946, and by July Captain P.W. Burnett, DSO, DSC, RN, the Assistant Director in DTASW responsible for anti-submarine warfare as AD(A/S) had a draft ready of a paper on the sea and air aspects of anti-submarine search and convoy defence. The complementary paper on aspects of fleet defence followed shortly afterwards. The papers were drafted in co-operation with Group Captain F.J. Finnigan, D of Ops, in the Air Ministry. After a detailed description of the anti-submarine situation at the end of the war, based heavily on Burnett's own experiences (and those of Ormsby and Mosse in his team), the papers moved on to explain the effect of the submarine's improved performance on post-war anti-submarine warfare.[434] They were intended as statements of how, over the next five years, A/S forces equipped with existing weapons and sensors, could deal with submarines whose performance equated to the 15-knot wartime German Type XXI. The papers were therefore to be the basis for training and exercise planning for the immediate future. This was the most pressing issue. The longer term problem of the 25-knot submarine was to be explored in detail once the urgent tactical problems against the 15-knot submarine were worked out. There was some pressure to consider this long-term problem sooner, for '...the escort vessels, A/S aircraft and carriers being designed now which will have to be used initially against the long-term (25 knot) submarine.'[435] These longer term investigations would also have to take into account other equipment, not currently in use in British forces, such as MAD and the Airborne Search (radio) Receiver.

The "Search and Convoy Defence" paper, unlike that on "Fleet Defence", began by surveying offensive A/S search in ocean waters before considering the problems of convoy defence. This ordering reflected the inherent desire for offensive operations (as

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433 'Joint Paper on Sea and Air Aspects of Fleet Defence against Submarines,' F.J. Finnigan, Director of Operations, Air Ministry, Captain G. Willoughby, DNAW and Captain Lord Ashbourne, DTASW, Admiralty, TASW.4261/46, [1 November 1946], ADM 1/20936, Covering Letter.

434 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2.

435 'General Implications of Improved Submarine Performance,' Section II, 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 5.

likely to lead to decisive results), but did not mark a shift in the policy which remained firmly rooted in the idea that convoy was the bedrock of A/S operations. Indeed, when the draft paper was discussed at the fourth meeting of the Tactical and Training Sub-Committee of the Sea/Air Warfare Committee it was decided that, should a conflict arise between investigations of offensive and defensive operations, the latter was to take priority.[436] The pre-war analysis of the limitations of striking forces had been confirmed by wartime experience as was outlined in Chapters 1 and 2. Even when the U-boats' submerged speed was relatively limited, there might not be sufficient ships to search the whole of the area in which an evading submarine could be, especially when the ships arrived at the datum after some considerable delay. It was usually necessary to limit the search to an area covering the submarines most likely escape course. A U-boat evading at only 5 knots required at least two ships to achieve a 50% chance of detection, and then only if the escorts were able to close an accurate datum position from no more than five miles away.[437] The increased submerged speed and endurance of modern submarines forced Senior Officers to assess even narrower limits than before on the submarine's probable action in order to achieve any reasonably prospect of detection. The keys to the problem were, firstly, to improve the accuracy of datum position reporting relative to the A/S ships and, secondly, to ensure that the ships arrived at the datum as quickly as possible, so that the area to be searched would be a small as possible. The means of fixing the datum relative to the ships depended on the source of the locating information. An aircraft, for example, might be able to report the datum accurately if, simultaneously, it held the approaching ships on radar.

Alternatively, if the datum was reported geographically (assuming this report was accurate), then the ships needed a means of establishing their own position exactly, say by the use of a radio navigation aid. Of course, the ships themselves might provide the datum position, perhaps from a number of ship-borne D/F bearings, though this would be limited if the submarines used "Squash". There was also the idea that the datum could be marked by a radio beacon, perhaps fitted to a ship that had been torpedoed. The ships, of course, could home onto the radio transmissions made by an aircraft circling the datum. But the A/S ships not only needed accurately to know were they were going, but also had to arrive as expeditiously as possible. Poor communications was a major contributor to errors in establishing accurate and timely

[436] 'Minutes of the Fourth Meeting of the Tactical and Training Sub-Committee of the Joint Sea/Air Warfare Committee...,' J.L. Crosbie and G.R. Carver, Joint Secretaries, Sub-SAWC/II/9/46, 19 July 1946, ADM 116/5614.
[437] 'Conduct of Anti-U-Boat Operations: Part IV, Air and Surface A/S Searches and Striking Forces' DASW, ASW 3078/43, BR1679(4), June 1944, ADM 234/293.

datum positions, as well as delays in getting ships moving in the right direction. Given that speed was of the essence, the captains of A/S ships needed to use their initiative in following up contact reports, and this could be stifled by an inflexible command organisation. Unavoidably, ships unfavourably positioned in the first place would take longer to arrive at the datum.[438]

Preliminary investigations using tactical tables had been going on at Osprey and Londonderry for some time.[439] Doubtless these confirmed that a submarine capable of high underwater speed would be able to evade '...the normal unit of 4 to 6 ships provided she can estimate its line of advance accurately and in time to use her high submerged speed without fear of Hydrophone detection.'[440] A/S ships approaching a datum, therefore, had to try to camouflage their mean course by apparently random zig-zags. For a single ship within 10 miles of a datum, the indirect approach used in the wartime "Beta" search could be adapted.[441] If more ships were involved, they should approach the datum using independent zig zags while trying to maintain a coherent search front. But even such artifice would not guarantee that the submarine would be detected on the first pass through the datum. Nor would it then be possible to search the whole area into which the submarine could have evaded. Some guess of the likely evasion course had to be made and the search concentrated around this assumption. The paper recommended that for longer range searches an "Observant" search should be used to contain the target, while for shorter range searches, where the A/S ships arrived at the datum quicker, a search based on the "Vignot" principle could be used so that the search spiralled (normally) outwards keeping pace with the submarine's furthest-on position. In US parlance these were known as "Retiring Search" plans, which approximated to an outward spiral track starting at the datum and designed to intercept the expanding furthest-on position of the U-boat.[442]

The ability of aircraft to locate and destroy submarines had not improved since the end of the war and it was expected that they would not regain the effectiveness enjoyed in 1943 until new or improved initial detecting equipment was in use. It was the long detection ranges achieved against surfaced U-boats, combined with the aircraft's high speed which gave the A/S aircraft a high search rate and its greatest potency

[438] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 5.
[439] 'Summary of DTASW's Investigation...,' ADM 1/20960.
[440] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 5.
[441] 'Conduct of Anti-U-Boat Operations: Part IV, Air and Surface A/S Searches and Striking Forces' DASW, ASW 3078/43, BR1679(4), June 1944, ADM 234/293. pp. 23-25.
[442] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, pp. 5-6; 'US Fleet, Anti-Submarine and Escort of Convoy Instructions (BUSCIs),' FTP 223A, January 1945, File 79/532, DHH, p. 1-5.

against U-boats by denying them security on the surface and hence the mobility needed to close their targets. Even before aircraft had developed a high lethality in attacks, U-boats had preferred to submerge on sighting an aircraft to avoid the chance of even minor damage. But from 1944 onwards this had changed for the worse, from Coastal Command's point of view. It had been the introduction of the schnorkel, and the consequent continuous submerged operations by the U-boats that had denied Coastal Command aircraft of their wide area search capability. The advent of this device had reduced the aircraft's detection range against submarines from some 16 miles to three quarters of a mile, or less in poor weather conditions.[443] Without a visible point of aim aircraft attacks with depth-charges or RPs would have very little chance of success.

During the war Coastal Command aircraft had been equipped with sonobuoys which could be dropped in the vicinity of a U-boat that had already been detected by some other means. Contact could be maintained on a submerged submarine, provided it was travelling at a speed and depth conducive to propeller cavitation. These sonobuoys, however, were not suited to wide area search because of their low performance which would require very large numbers to be used. Nor could these sonobuoys be used in the vicinity of a convoy because the noise of the convoy at a range, say, of five miles, would drown the HE signature of a submarine only one mile from a buoy. It was thought that directional sonobuoys would enjoy greater effectiveness in this situation. No British specimens of these types existed in 1946, though a few US buoys were due to arrive in Britain for evaluation. British directional sonobuoys were unlikely to be well advanced until 1948.[444] Also during the war the Americans had used MAD equipment with some success. Its detection range, however, was extremely short, so that the use of this equipment was limited to small area searches. An early version had been developed by the British but had never been adopted by the RAF.[445] The prospects for aircraft were not good, for aircraft had little chance of detecting submarines that were in transit or on patrol. However, they could at

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443 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 3.

444 'Report by DOR(E) on Sonobuoys – British/American Standardisation,' Air Commodore G.W. Tuttle, DOR(E), C.34223/47 and Sub-SAWC/II/54/48, 4 August 1948, ADM 116/5819; 'First Commonwealth TAS Liaison Meeting [10-20 October 1949] – Report by RAN Representative,' Lieutenant Commander I.K. Purvis, RAN, n.d., NAA(M), MP 1185/8, 1846/4/343.

445 'MAD, Question of Fitting in our A/S Aircraft,' DACD, ACD.33/42, 12 September 1942, ADM 1/11741; 'Test of MAD Equipment for Detecting the Presence of Submerged Submarines from the Air,' Coastal Command Development Unit, RAF Tain, Ross-shire, Report No. 87, CCDU/20/122/AIR, 3 December 1942, File S-28-1-4, Vol. 5271, RG 24, NAC; P.M.S. Blackett, 'Evan James Williams. 1903-1945,' in *Obituary Notices of Fellows of The Royal Society*, 1945-1948, Vol. V (London: Morrison & Gibb for The Royal Society, 1945-1948), p. 396; Professor Westcott, Letter, 28 June 1998; Flight Lieutenant Bell, Letter, 1 July 1998.

least keep the submarines submerged and, there was the possibility of submarines being badly handled, giving the A/S aircraft an opportunity for attack. Overall, however, is seemed that aircraft would '...probably not again prove as effective as they did in 1943 until a new initial detecting device is in use.'[446]

It seemed likely, therefore, that the main burden of searching would fall principally on the A/S ships. However, it was hoped that aircraft would provide positive assistance by accurately fixing a datum and homing the hunting ships onto its location. It would be especially helpful if the aircraft was able to report the position relative to the ships, say by using radar, and thereby eliminating the navigational errors inherent in geographic reporting. The A/S aircraft would also be able to confirm that the U-boat had not attempted to escape on the surface and if a suitable pattern of sonobuoys were used, it would also be able to assess whether the submarine had used high underwater speed to evade. The presence of the aircraft would also deter the submarine from using its periscope to ascertain the approach of the hunting ships. These measures would assist the ships in their search by refining the area to be searched, either by confirming the U-boat had not used high speed, or providing some idea of the direction of escape if it had. At the same time, if the enemy submarine was not able to freely use its periscope, it would have less knowledge with which to assess the best course for evasion. For such sea/air co-operative tactics to work effectively, good communications and mutual understanding would be even more important than they had been in the past. This would be assured by the induction and continuation training courses being set up by the Joint Anti-Submarine School at Londonderry.

Having dealt with offensive operations, Burnett and his team moved on to consider the problems of trade protection and later Fleet defence against submarines with high underwater speed and endurance. The counter-measures in both cases show a congruence, though the high speed expected of the Fleet on passage and the higher degree of protection made significant differences in the mode of anti-submarine operation. In both cases, the Limiting Lines of Submerged Approach would now describe a much larger sector from which a modern high-speed, schnorkel-fitted submarine could approach. The distance between the Lines would be longer and would require more A/S ships to cover it. In addition, if escorts were to have a chance of destroying an attacking U-boat, they would need more "fighting room" than had been needed against the older, slower U-boat during the war, when it had been practice for escorts to be stationed at ranges of 1½-2 miles from the convoy during the day, and

[446] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 6.

2½ miles by night (when surface, and hence higher speed, attack by U-boats was more likely).[447] Now some of the escorts would have to be stationed further out from a convoy, perhaps as far as 3-4 miles.

The same principle was established for the screen ahead of Fleet units, which was advanced to some 3 miles, instead of the wartime 2 miles. So that a least two escorts could concentrate against an approaching U-boat, their overall dispositions would need to be arranged to provide "defence in depth". This was especially important in Fleet defence, for the detecting ship might not have time to turn to counter-attack, given the high relative closing speed of the submarine and the main body of the Fleet. Of course, there was still no idea that a convoy's escort could provide an interlocking asdic front, as was expected for Fleet protection. In both cases, however, if escorts were to be disposed further out, then larger numbers of A/S ships would be needed to provide the same degree of cover as given to wartime convoys or the Fleet. It was felt that the submarines would still favour firing torpedoes at close range from a position broad on the bow of their target. However, improvements in torpedo firing ranges and the use of homing or pattern-running programmes, would give submarines the option of firing, not only from longer ranges, but from all compass bearings. Such shots had been practiced during the late war, though not with great success, for long range attacks posed severe fire control problems for the submarine.[448] Escorts would, therefore, have to provide cover on bearings abaft the beam of a convoy or Fleet. In the latter case, account would also have to be taken of the requirement for aircraft carriers to turn into wind for extended periods to launch and recover aircraft. Since this heading was unlikely to be the same as the mean line of advance, it was likely that A/S escorts would have to form a "circular" screen around the Fleet. This was reminiscent of the screens formed to cover convoys and Fleet units in the Arctic and Mediterranean during the war.

Support groups had been formed early on in the war and had been used to reinforce threatened convoys, though not Fleet units. During the later phase of the U-boat campaign in inshore waters, relatively weak close escorts had been provided, while support groups were stationed in geographic areas where U-boat activity was expected either from attacks or intelligence. For a future A/S campaign, Burnett thought, the majority of escorts would, once more, be more effectively deployed in support groups, provided there was sufficient intelligence of the enemy's patrol areas.

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447 'Convoy A/S Escort,' in, 'Conduct of Anti-U-Boat Operations, 1940,' DASW, ASW.2191/40, CB4097(11)(42), November 1940 [with amendments to 25 April 1945], Box 468, RG 38, NARA2, Plates 4-7.
448 Compton-Hall, 26 February 2000.

Burnett considered it more likely that these support groups would be used directly to augment the convoy's close escort, just as they had done in the latter stages of the war. Earlier in the war it appears that the support groups tended to patrol at a distance around the convoys to deter surfaced U-boats from using their high speed to gain ground so that they could make an attack. Now, with submarines likely to remain submerged distant patrols would have less effect, and A/S escorts would be better placed close to the convoy from where they could either detect submarines as they manoeuvred into a firing position, or counter-attack them if they had penetrated the escort line. Of course, if the total escort force was sufficiently powerful, it might still be possible to detach some A/S ships to patrol further afield where they might be able to harass submarines concentrating against the convoy. These ships could also be used to follow up contacts made, say by aircraft, at a distance from the convoy. This could also apply to Fleet screens, though here the problem was that the detached vessels would have to steam at very high speed to catch up the main body, which would cause a heavy expenditure of fuel.

As for air support, the paper reiterated that the chance of aircraft detecting submarines travelling deep or at slow speed was small. The best that aircraft could achieve was, by the use of sonobuoys, radar and visual search, to deter submarines from using the surface to snort or use their periscopes and radar aerials with impunity. If a submarine were detected and its position known within reasonable limits, it was possible for an aircraft to track it with sonobuoys for a limited period of time, provided the submarine was travelling at speed. Burnett, who had experience of this type of ship-air co-operation, thought that the absence of contact should lead to the assumption that the submarine was evading at low speed. The A/S vessels would then have to search a smaller area. Even relatively sparse air patrols would make it extremely hazardous for submarines to travel on the surface to close a convoy or gain bearing once in contact. During the war U-boats attacking submerged had to get into a relatively small sector ahead of the convoy or Fleet. Aircraft had not paid a great deal of attention to this sector because of their ineffectiveness in detecting submerged U-boats. Now, however, with their greatly increased submerged speed and endurance, submarines were able to close to a firing position from a much broader sector. The aircrafts' ability to detect the submarine were little better than during the war, so it was now felt that they could be most useful when patrolling this sector immediately ahead of the convoy's or Fleet's escort. Here, in what became known as the "look zone", a submarine might wish to make last minute, high speed adjustments to get into a firing position, or to use their periscope or radar mast to confirm the point at which to penetrate the A/S escort, or to refine the submarine's fire control solution. A submarine with the characteristics of the Type XXI would be able to intercept a convoy from great distance off track, if it were ahead of the convoy, but would be unable to close from far astern without surfacing. If air patrols were therefore extended to cover the aft sectors they would provide a considerable degree of protection. This would, in turn, allow the surface escorts to concentrate on the most dangerous sectors forward of the convoy's beam.

This system of air and surface escort, the papers emphasized, would benefit from close co-operation between all the forces involved. There was a need to resolve the division of responsibilities when both carrier-borne and land-based aircraft were operating in support of an individual convoy. But this apart, the co-operation of the air force and naval forces was already being fostered by the work of the Admiralty and Air Ministry Joint Sea/Air Warfare Committee, the Area Combined Headquarters (AHQs), and the teaching of the Joint Anti-Submarine School at Londonderry. As far as the latter was concerned, a crucial function would be the development of A/S tactics, especially '...to specify more definitely than has been done in the past the immediate action which should be taken if a submarine gets in its attack undetected.' This was, marginally, already better covered for convoy defence from wartime experience, though not against fast submarines. In any case, the tactical instruction now needed to combine surface and air actions, and which would be applicable world-wide.[449]

The joint papers made a number of recommendations. So that the Admiralty's and Air Ministry's '...present trend of thought in these matters...' was understood, the papers were to be forwarded to the British Naval and Air Commanders-in-Chief, and the relevant training and experimental establishments, as well as the Dominion Naval and Air Headquarters. As for future progress the key was to establish the best methods of search in open ocean operations and for trade defence using combined air and sea A/S forces. Of these, trade protection was seen as the first priority. The Joint Anti-Submarine School at Londonderry, which was already investigating the convoy problems, was, in consultation with Headquarters Coastal Command, to propose tactical schemes, given current equipment. These schemes were to

> ...then be considered by the operational and research departments on purely mathematical lines and then returned to the Command and the School so that

[449] 'Joint Paper on...Fleet Defence...,' ADM 1/20936, *passim*; 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, *passim*.

investigations could be started, first on the tactical table and subsequently in practical sea trials.[450]

Similar requests were made to Cs-in-C, Home Fleet and Coastal Command on the air and surface screening requirements for the Fleet. Initially all these investigations were to concentrate on the "short-term" problem of submarines with performance comparable to the German Type XXI and employing current A/S equipment. Thereafter thought would be needed on how to counter the future "long-term" problem of the 25 knot, Walter-type submarine.[451]

The Ability of Future Submarines to Make Contact

DTASW was concerned with developing a realistic basis for a review of the A/S doctrine to deal with the modern schnorkel-fitted, high-speed submarine. These submarines would, of course, operate underwater, which gave them a certain degree of immunity, particularly from air attack but these tactics also inhibited the submarine's ability to find its targets, without the help of air reconnaissance or accurate intelligence. This issue had been discussed at a Tactical Staff Meeting in the Admiralty, presided over by DCNS, in December 1946 and resulted in Admiral G.N. Oliver, ACNS, calling for a joint appreciation on the matter from DTASW and DAW.[452] Ashbourne opened the process by considering each of the methods a submarine could use to detect its prey. The periscope was the primary method and in good weather the following table shows the ranges to be expected, compared with those from the bridge of a surfaced submarine:

	Large Warships	Merchant Ships	Escorts
By periscope	14 miles	12 miles	10 miles
On bridge on the surface	18 miles	15 miles	13 miles

However, periscope observation was, by its nature, intermittent, so that the maximum ranges would not always be achieved. Poor visibility and rough weather would also substantially reduce these ranges. In a 15-foot sea, for instance, the visual distance through the periscope would be practically zero, while at night, with the existing technology, ranges were extremely limited in any sea state. At high speed no periscope observation could be made. Ashbourne estimated, taking all these factors into account, that average ranges would be roughly:

[450] 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2, p. 10.
[451] 'Joint Paper on...Fleet Defence...,' ADM 1/20936, p. 6.
[452] Memorandum by G.N. Oliver, ACNS, 31 December 1946, ADM 1/20384.

	Large Warships	Merchant Ships	Escorts
By periscope	10 miles	9 miles	7 miles

The Germans had made great use of hydrophone detections, and it was assumed that the Russians would learn these techniques. Acoustic ranges vary significantly, depending, amongst other things on, the depth of water, and the speed and size of the target. The noisiest targets (high speed Fleet units or convoys) might be detected at 20 miles, provided the submarine itself was travelling at slow speed. The British and Americans were making use of radar in submarines, though detections from periscope depth were unlikely to be at a range greater than that obtained by visual means unless the visibility was poor. As with normal periscope observation the submarine would be unable to use radar when travelling at high speed. In addition, use of radar by the submarine exposed it to counter-detection by escorts fitted with suitable search receivers. The reverse of this was also true, that is, submarines could make use of detections of radar (or W/T) transmissions from escorts. Lastly, the enemy submarine might be fed intelligence information from its operational headquarters ashore.

Ashbourne concluded that the submarine of the future, limited to its own resources, would have less opportunity of detecting its targets than had the submersible of the late war. 'It will be practically blind when proceeding at high speed,' Ashbourne noted, and harking back to the debilitating problem faced by the Germans throughout the war, he deduced '...that if the submarine of the future is to make use of its strategic mobility, it will require reconnaissance of its targets and accurate direction onto them.' From this Ashbourne concluded that if the modern submarine could be denied air reconnaissance, then a proportion of the operational submarine force would have to be used passively in the reconnaissance role.[453]

The convoy strategy continued to influence the enemy's approach:

> In February 1943, when Dönitz had just become C-in-C of the German Navy, a memorandum from the German Naval Staff to the Air Force Command Staff contained these words:
>
> > 'Our submarines are operating in steadily increasing numbers without positive results.... All efforts of the Naval Staff to maintain contact with enemy convoys by assigning more submarines or by repeatedly changing the operational areas, are limited by the vast distances of the Atlantic and by the resulting difficulty of establishing contacts with convoys far away from their point of assembly or port of destination. We must continue to gain a maximum of information about the course of the enemy convoys if the Battle of the Atlantic is to remain successful. This can be done only by means of air

[453] 'Ability of the Submarine of the Future to Make Contacts,' [Captain Lord Ashbourne, DTASW, 28 January 1947], ADM 1/20384.

> reconnaissance. Aircraft must penetrate to mid-Atlantic; aircraft must locate the convoys; aircraft must keep contact with these convoys; and aircraft must lead the submarines to the targets."

A Naval Staff comment some months later said:

> "The new submarines, even more so that the earlier types, depend on aircraft for observation at sea."[454]

At the end of January 1947, having received Ashbourne's input, Captain E.H. Shattock, the Director of Air Warfare, produced his appreciation to answer the question: 'Can we prevent this air reconnaissance, or make it too expensive for the enemy to keep up?'[455] There were, in fact, two problems to solve, Shattock realized: preventing the enemy's searching and, separately, denying him the ability to shadow located targets. He thought that searching, particularly for slow-moving convoys, would require only a few fixes per day in the Western Approaches for the enemy to have a good idea of the shipping movements. There were three broad possible types of search the enemy could adopt. He could sweep the area with fast, high-flying aircraft fitted with ASV capable of detecting a convoy at a range of about 80 miles. This would employ, perhaps 20 aircraft per day and these flights would rely on their height and speed to avoid interception by fighters. It ought to be possible, Shattock thought, to detect these aircraft at long range. This meant that high-performance fighters could operate from deck-alert, thus obviating the need for standing air patrols, which were expensive in aircraft numbers. Deck-alert would probably require only 6 high-performance fighters to protect each convoy, but these could only be operated from modernized carriers. It seemed, he conjectured, unlikely that there would be sufficient numbers of modernized carriers to undertake the task, making the chances of stopping this type of reconnaissance remote.

The Russians could use slower aircraft carrying high-powered Airborne Early Warning (AEW) radar that could detect convoys at about 200 miles. Clearly, far fewer aircraft would be needed for this method, but their lower performance would make them vulnerable to fighters. However, even if ship's radars could be improved to allow direction of the interception at these long ranges, the fighters may not have enough endurance, added to which, if the AEW aircraft were handled intelligently, the fighter director's task might be impossible. The last method, Shattock considered, was the use of low-flying aircraft, which relied on remaining below radar coverage of the convoy for their own safety. This flight altitude, however, would reduce their performance

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454 'Proposed Paper for Policy and Plans Sub-Committee [Air Reconnaissance for Submarines of the Future],' [Captain A.N.C. Bingley, DNAW, 26 June 1947], ADM 1/20384.

455 'Prevention of Enemy Air Reconnaissance Co-operating with Submarines: Appreciation,' [Captain E.H. Shattock, DNAW, 5 February 1947], ADM 1/20384.

(especially if jet-powered) and limit their individual search capability. Although their performance was relatively limited, the warning given of their approach would mean that fighters would have to be kept on airborne patrol to stand a chance of intercepting. This would mean that there would have to be about 6 aircraft on the carrier for every one aloft on patrol, and this would, in turn, exclude the carrying of any A/S aircraft. Only by such measures would it be possible to shoot down these low-flying reconnaissance aircraft. On the other hand, the enemy would have to use large numbers of aircraft to complete his task.

For the Russians, the shadowing task was more difficult. Aircraft would have to remain in contact, while the submarines were concentrating on the target. AEW aircraft might be able to achieve this, relying on their long range from the convoy for safety. However, these types were more open to radar deception and their reports might not be sufficiently accurate for the submarines due to the technical limitations of the AEW sets. For the other types of enemy aircraft, the close shadowing which they would have to contemplate could be made expensive, Shattock thought, since there were likely to be repeated opportunities for the defence to intercept them. Efficient shadowing was probably preventable, Shattock concluded, provided threatened convoys could be given carrier-borne fighter protection. He did consider the use of RAF shore-based long-range fighters, but the obstacles seemed to be overwhelming, given the problems of fighter endurance versus performance and the need for long-range control of the interceptions. As a result of this appreciation, Shattock considered that it was unlikely that the enemy could be denied reconnaissance of the convoy routes without a huge deployment of modernized aircraft carriers and this seemed '...a most unlikely proviso....'[456] It seemed reasonable to suppose that fighter cover could be provided to threatened convoys, and therefore, there appeared to be a good prospect of preventing, or at least discouraging, the enemy's efficient shadowing of convoys. Shattock felt that the whole problem needed to be explored further in a series of tactical table games and large scale exercises at sea.

In the spring of 1947 the NID circulated a US Office of Naval Intelligence report based on German Naval Staff documents which reinforced the issue of air reconnaissance support for U-boat operations. 'The lesson for us is clear,' ACNS minuted,

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[456] 'Prevention of Enemy Air Reconnaissance Co-operating with Submarines: Appreciation,' [Captain E.H. Shattock, DNAW, 5 February 1947], ADM 1/20384.

> The interception and destruction of enemy long distance over-sea reconnaissance aircraft must go hand-in-hand with the attack and destruction of the U-boats themselves.[457]

He proposed that the Sea/Air Warfare Committee should review the problem to encourage work in this area. In June DAW forwarded the final version of the appreciation on the prevention of enemy air reconnaissance co-operating with enemy submarines, which took account of staff comments within the Admiralty and Air Ministry, and by Flag Officer, Submarines, as well as incorporating the historical perspective from the German experience.[458]

In the spring of 1947, E.M. Gollin, the young and brilliant new Director of Operational Research (DOR) at the Admiralty, minuted some thoughts on a future anti-submarine campaign.[459] He had worked in NID and now began by noting that:

> From the purely economic viewpoint, shipping should sail in convoy rather than independently if more imports would thus be obtained over the total period of a war at sea, i.e., if the gain in imports arising from the reduction of casualties exceeded the loss in imports arising from the delays of the convoy system. Very roughly, it is estimated that against an enemy effort represented by about 15 (or more) U-boats continuously on patrol...convoys should be instituted in a war at sea lasting 6 month or longer.[460]

But, Gollin explained, just sailing of ships in convoy, instead of independently, would not appreciably reduce the submarines' ability to make contact in focal areas. Each convoy in the focal areas would have to be given a full escort capable of preventing the attack by most of the U-boats making contact, or, at least, inflicting a severe loss-rate upon them. At least eight escorts per convoy would be required. The primary aim of future A/S operations was, therefore, to initially drive enemy submarines out of the focal areas and into the open ocean, where they would have to rely on intelligence for knowledge of shipping movements. Outside the focal areas shipping sailed in convoys, even with a token escort, would, Gollin reasoned, probably greatly reduce submarines' ability to locate convoys, unless Russian Intelligence was extremely good. Even then, the Russians would need the tactical and technical skill to conduct pack operations. The complementary tactics of reconnaissance and pack operations were necessary if the scale of attack against individual convoys was to be increased. It followed, Gollin deduced, that

> ...the escort force required to keep losses at an acceptable level depends primarily on the scale of attack which can be mounted against an individual convoy, rather

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[457] Minute, G.N. Oliver, ACNS, 18 April 1947, ADM 1/20384.
[458] 'Proposed Paper for Policy and Plans Sub-Committee [Air Reconnaissance for Submarines of the Future],' [Captain A.N.C. Bingley, DNAW, 26 June 1947], ADM 1/20384.
[459] Minute by F. Brundrett, MA, DDSR, 17 December 1945, ADM 1/20113.
[460] Minute, E.M. Gollin, Director of Operational Research, 1 April 1947, ADM 1/20030.

> than on the total size of the U-boat fleet; the nature of this dependence is complex, and the present knowledge of tactics, weapons and efficiency of a future enemy is insufficient to define it.[461]

He also noted that the effect of an increased enemy attack could also be mitigated by alterations to the convoy system itself. Perhaps drawing on the wartime work on convoy size, Gollin thought,

> if the number of U-boats at sea increased, the total imports over a period might well be maintained by sailing few but larger convoys; the slower turn-round being offset by the greater safety of an individual ship in a larger convoy, by the greater number of escorts per convoy made possible by the new cycle, and – outside focal areas – by a smaller number of convoy attacked. This last factor would arise if U-boats were denied good intelligence.[462]

Of course, if the scale of attack (and therefore losses in convoy) were contained, then the convoy cycle could be adjusted to run greater numbers of smaller convoys, which would improve the overall delivery rate.

In Gollin's view the ability of the Russian's to gather the necessary intelligence of shipping movements from use of AEW aircraft was overrated. Even the British, he thought, with their superior radar research capability could not produce an aircraft of this type within the next 5 years and it seemed very unlikely that the Russians could better this timescale. Nevertheless, in terms of counter-measures to submarine attack on convoys, Gollin noted that hitherto the prime function of the escort had been to prevent U-boats from carrying out a torpedo attack. Now, however, directly countering submarines which fired at long range would require a prohibitively large escort force. Might it not be more realistic, he wondered, to plan for future escorts avenging attacks rather than trying to prevent them – a tactic frequently used in the difficult circumstances of the interwar years and during the inshore campaign of 1944-45. Gollin thought that escort might be armed with long-range A/S torpedoes which could be counter-fired against attacking submarines whose position would be estimated from the detection of their torpedoes. The escorts would also have to be able to cope with submarines which attempted to hide beneath the convoy. In either case, two escorts might be detached to hunt the submarine in co-operation with aircraft or helicopters. Sonobuoys would be used to detect the submarine if it tried to escape at high speed, thus giving the escorts the chance to gain asdic contact. Otherwise, if the submarine

[461] Minute, E.M. Gollin, Director of Operational Research, 1 April 1947, ADM 1/20030.
[462] Minute, E.M. Gollin, Director of Operational Research, 1 April 1947, ADM 1/20030; Llewellyn-Jones, 'A Clash of Cultures,' pp. 138-166.

used slow speed, the area to be searched by the escorts would be relatively small, giving them a better chance of success.[463]

Captain P.G. Cazalet, in D of P, made some comments on Gollin's minute. He expressed the common view, when he pointed out that, in a future war, most of the Atlantic coast-line would probably fall into Russian hands at an early stage. Clearly, this would repeat the strategic problems posed in 1940 by the German occupation of the Biscay ports. He also thought that, because of '...the lowly place occupied by the Russian Navy *vis-à-vis* the other Services, its inexperience, and its difficult training conditions...they will [amongst other things] exploit maritime Air Forces.'[464] The requirement to provide A/A support for convoys would place an additional heavy strain on British escort forces. Cazalet also observed that Gollin had not taken into account the use of fast, high-flying ASV-fitted aircraft in the reconnaissance role, which had been considered by DAW. This was a theme developed further by Captain H.P. Currey in the Tactical and Staff Duties Division (DTSD), who pointed out that Exercise "Spearhead", a combined exercise involving all three services, that had been held at Camberley in late 1946, had shown up the enormous numbers that would be required in the future, not only of A/S escorts, but A/A and air-direction (A/D) types as well to cope with the anticipated Russian air threat against shipping. A second exercise followed in early May 1947 which again emphasized the problems of defending seaborne military and trade shipping against modern combined air and submarine attack.[465] Currey observed that, with a Russian occupation of the Atlantic coast, '...the striking range of enemy submarine and aircraft will be greatly extended and our defences stretched to a point which we have never known in the past.' His assessment from this exercise, as well as other staff comments, was that the British had probably reached the point where the number of escorts required for the protection of vital shipping in war was prohibitive and beyond both manpower and building capacity. It seemed to Currey that

> ...the time has now come when we must face the fact that the purely defensive policy of endeavouring to surround each of our many convoys with an effective A/S and A/A screen is no longer practicable and that we must turn our attention and efforts more towards offensive measures rather than defensive measures.[466]

He thought the most obvious methods were the direct attack-at-source on the enemy's submarine bases and airfields, his communications and industrial capacity. Currey did

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463 Minute, E.M. Gollin, Director of Operational Research, 1 April 1947, ADM 1/20030.
464 Minute, Peter Cazalet, for D of P, 22 April 1947, ADM 1/20030.
465 'Exercise "Spearhead",' in, 'Progress in Tactics: 1947,' DTSD, CB03016/47, 17 October 1947, ADM 239/143, pp. 45-46.
466 Minute, Philip Currey, for DTSD, 29 April 1947, ADM 1/20030.

not contemplate the use of atomic weapons, but did note that the effort with conventional bombing would require substantial resources, and that in the early stages of a war these assets were unlikely to be available. He considered, therefore, that other means would be needed, including the use of mines, small battle units directly against submarine bases, and a blockade by submarines in the A/S role. Even so, he pointed out that defensive measures around convoys would still be needed. Finally, to reduce the onerous nature of this task, Currey suggested that means should be explored of shifting a proportion of the extensive British coastal seaborne trade to inland routes. The ACNS, Oliver agreed with the staff comments and passed the docket on to Vice Admiral Sir Rhoderick McGrigor, Vice Chief of Naval Staff (VCNS), for information.[467] McGrigor considered the large numbers of escorts forecast to deal with the Russian threat was wildly optimistic. 'We need,' he thought,

> ...a lot of clear thinking on the subject of the future escort, and when considering staff requirements, the need for speed, killing power, specialised duty, and so on, the over-riding problems of numbers must be kept clearly in mind, which means mass production, simplicity, and sacrifices of many desirable qualities.[468]

Although the Naval Staff recognised the importance of enhancing methods of attack-at-source, there remained a clear commitment to "defensive" convoy operations. It was also established during this period, after a protracted and, at times, obscure debate, that the risk of major war was to be taken as low over the five years from 1947, though the risk would progressively increase over the subsequent five years.[469] In the meantime McGrigor directed that "...a lot of clear thinking" was required. Burnett was already drafting a major paper on the technical and tactical problems which had to be resolved over the next few years. The process was one in which the Americans also took a close interest, as the extended visit of the US Assistant Chief of Naval Operations (Operations), Rear Admiral C.W. Styer, USN, was to show.

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[467] Minute, G.N. Oliver, ACNS, 5 May 1947, ADM 1/20030.
[468] Minute, [Vice Admiral Sir Rhoderick McGrigor, VCNS], 7 May [1947], ADM 1/20030.
[469] Minute, D of P, 20 August 1947, ADM 116/5966; Minute, USS, 23 October 1947, ADM 116/5966; Eric J. Grove, 'The Post War "Ten Year Rule" - Myth and Reality,' *Journal of the Royal United Services Institute*, Vol. 129, No. 4 (December 1984), pp. 48-53.

Chapter 6: New Problems, Old Recipes, 1947-1948

Anti-Submarine Problems of the Future and Attack-at-Source

Admiral Styer's visit was timely. During 1946 the Americans were concerned, as they put it, to provide '...a more sharply headed up organization...' to deal with the anti-submarine aspects of Operational Readiness and Fleet Operations. As a result, Rear Admiral C.W. Styer, USN, was assigned additional duty as the "Coordinator of Undersea Warfare" throughout the USN.[470] Styer, a submariner by profession, and a team of USN officers visited every British anti-submarine establishment, and all the command and staff division in early 1947. The visit impressed Styer and he left with the firm conviction that the British anti-submarine warfare planning system '...is excellent, well organized, and is worth consideration for our adoption either in toto or a suitable modified form.'[471] While in Britain he was given a series of briefings by the Admiralty, including one by Ashbourne outlining an Admiralty and Air Ministry "Review of the Problems of Future A/S Warfare". Dealing only with the "Short-Term Problem", Ashbourne outlined the technical and tactical issues for Styer from both the naval and air force perspective. 'Two major factors,' he said,

> ...will influence our defensive dispositions round convoys or Fleet units:–
>
> (a) Submarines are less likely to be on the surface when concentrating or shadowing, so that the presence of our forces in the deep field is less likely to provide warning of the submarine's approach, and will be less hindrance to the submarines.
>
> (b) Submarines will probably fire their torpedoes from longer ranges and the screening vessels will find them more slippery customers to detect and attack.

From these propositions, Ashbourne concluded that:

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470 'Proceedings of Anti-Submarine Warfare Conference, 17 June 1946,' Op-34H:jn (SC) A16-3(17) Serial: 00012P34, Forrest Sherman, Deputy Chief of Naval Operations, 25 June 1946, Post 1946 Command File, CNO Ser: Conferences, Anti-Submarine Warfare 1946-1948, Box 325A, OA, NHC.
471 'Report of Coordinator of Undersea Warfare and Assistants' Visit to British Naval Activities, Jan. 19 – Feb. 12 1947,' Forrest Sherman, Deputy Chief of Naval Operations (Operations), Op-31B:ch (SC) A16-3(17) Serial 003P31, 30 April 1947, Box 90, RG 313, NARA2, p. 2.

> ...all available surface escorts will be used in the screen and that this screen will be more a deep zone of escorts two to five miles round the convoy or Fleet [rather] than the wartime single line.[472]

He also suggested to Styer that in the future the navies should be prepared for a fundamental change in enemy submarine tactics. During the early part of the war it was rare for U-boats deliberately to target escorts, unless they posed a direct and immediate threat. That changed in late 1943, and during the last months of the war, one escort was lost for every two U-boats destroyed. In a future war, further improvements in acoustic homing torpedoes could persuade the enemy to intentionally sink escorts from the outset. At a time when escorts would be scarce, and production capacity not fully developed, such a strategy could soon leave convoys bereft of protection.

Apart from convoy, Ashbourne only mentioned one other strategic measure to Styer, that of deep minefields under the most important coastal routes. Doubtless this focus was due to Ashbourne's own wartime experience in minelaying operations. It was realized that these minefields, being sparsely laid, would not cause many casualties but would produce a constant worry for U-boat crews while on operations. Regarding air operations, the briefing given to Styer centred around the air escort of convoys. There was some discussion over the use of helicopters, fitted with a towed or dunking sonar but the main issue was the lack of progress in re-establishing the anti-submarine aircraft's ability to search large areas (which had been so important with radar-fitted aircraft against surfaced U-boats during the war). Although high priority was attached to developing an airborne A/S homing torpedo, deploying an operational version was a long way off. Aircraft, therefore, were relegated to the "scarecrow" role to ensure that enemy submarines operated submerged, thus limiting their strategic and tactical mobility and their ability to locate targets. Fighter aircraft would, it was thought, also be needed to shoot down enemy reconnaissance aircraft working with U-boats to locate convoys (though this, too, was to prove a difficult problem before the advent of high performance jet aircraft).[473] This was a regurgitation of the ideas outlined in Burnett's doctrine papers. Clearly, though, the British were already considering other alternatives, for when Styer visited Air Chief Marshal L.H. Slatter, AOC-in-C, Coastal Command, at Northwood the conversation turned to the co-ordinated use of air and surface craft in offensive anti-submarine operations in ocean waters.

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[472] 'Review of the Problems of Future A/S Warfare,' TASW.2014/47, [December 1946], in, 'Report of Coordinator of Undersea Warfare and Assistants' Visit to British Naval Activities, Jan. 19 – Feb. 12 1947,' Forrest Sherman, Deputy Chief of Naval Operations (Operations), Op-31B:ch (SC) A16-3(17) Serial 003P31, 30 April 1947, Box 90, RG 313, NARA2, p. 5.
[473] 'Review...Future A/S Warfare,' Box 90, RG 313, NARA2, pp. 6-8.

In late April 1947 Captain R.S. Warne, CBE, another submariner, relieved Ashbourne as DTASW. For the time being Burnett remained as AD(A/S) and, along with Ormsby and Mosse, expanded on the assessment of anti-submarine problems presented to Styer. The draft they produced was also used as a briefing paper to support Sir Henry Tizard's scientific liaison visit to America in August 1947. In the paper Burnett wrote that,

> ...the submarine and anti-submarine war at sea has depended on the ability of the submarine to remain invisible while improving its striking power, and the ability of the anti-submarine forces to locate the submarine, and neutralize its attack. At the moment the submarine is in the ascendent [sic] in the absence of any major improvement in the range of detection by existing apparatus, or in the absence of any new counter to its present "invisibility".[474]

When comparing own and enemy capabilities, Burnett thought it advisable to pitch existing British A/S capability against an assessment of an enemy's submarine potential of, say, 15 years hence. For the foreseeable future, there was no A/S detection system which offered a higher search rate to cope with the elusiveness of modern high-speed, long-endurance submarines. Furthermore, on being detected, these submarines could prove difficult to attack because of their great powers of evasion. It was hoped that by 1955 the new Limbo A/S mortar and Type 170 Asdic would largely overcome this disability, though it would take time for the equipment to be fitted fleet-wide and for the development of tactics as well as training in its use to be achieved. On the air side the picture was far gloomier. The development of effective sensors and weapons for aircraft would take much longer, and there remained many technical problems for which no solution was in sight. A more difficult dilemma, though outside the scope of Burnett's paper, was the provision of adequate numbers of escorts. It had been provisionally estimated that 500, or more, A/S vessels would be required, yet by the mid-1950s barely half this number would be available.

These difficulties had already persuaded Captain H.P. Currey, DTSD, that

> ...the time has now come when we must face the fact that the purely defensive policy of endeavouring to surround each of our convoys with an effective A/S and A/A screen is no longer practical and that we must turn our attention and efforts more towards offensive measures....[475]

Burnett agreed and pointed out that the history of British A/S warfare clearly showed that solely defensive measures had never been relied upon. During the First World War U-boats had to spend some 25% of each day on the surface, simply to charge their batteries. Convoy escorts and hunting patrols had no means of accurately locating U-

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[474] 'Anti-Submarine Problems of the Future,' TASW.4666/47, P.W. Burnett, for DTASW, 16 August 1947, AIR 20/6381, Summary.
[475] Minute, Philip Currey, for DTSD, 29 April 1947, ADM 1/20030.

boats unless they were on the surface, yet convoy escorts accounted for 24 U-boats between July 1917 (when ocean convoy was introduced) and October 1918. Over the same period patrols destroyed 16 U-boats, 10 were sunk by submarines and 35 were lost in offensive and defensive minefields.[476] The work being carried out in the Historical Section on the Second World War was showing that while convoy escorts were, once again, the highest single means of killing U-boats, it was also true that roughly half of all the U-boats sunk were destroyed by the broad range of "offensive" A/S measures.[477]

At the beginning of the Second World War Burnett recalled that the British had not had enough patrols to prevent U-boats surfacing to charge their batteries. With growing numbers, tactical efficiency and the fitting of radar, the escorts and air patrols eventually made it too dangerous for the U-boats to operate in these strategically important focal shipping areas. The Germans were then forced into the wide ocean areas where, to find convoys, they had to rely even more on the high surface speed of their U-boats now operating in packs and controlled by wireless from the shore HQ. Air escorts made it difficult for U-boats to concentrate around convoys, usually enabling the surface escorts to drive off the limited numbers of U-boats that made contact. Initially, U-boats avoided asdic-fitted escorts by attacking at night on the surface but the widespread fitting of high-definition radar in escorts soon defeated this tactic. The intercept and D/F of enemy radio traffic – aided occasionally by the timely decryption of messages – also allowed support groups to reinforce threatened convoys. Tactically HF/DF permitted A/S escorts to disrupt individual U-boat attacks and often to destroy them. By 1944 the U-boats had been fitted with the schnorkel, which allowed them to charge their batteries submerged and remain largely immune to detection by aircraft. This heralded '...a new era of A/S warfare...' as the U-boats were able, once more, to return to the focal areas in UK waters. Here it was easier for them to find targets, which, in turn greatly reduced their reliance on the use wireless to find or attack convoys. Opportunities for exploiting U-boat transmissions were therefore limited, though the gradual disintegration of the German command structure with the advance of the Allied armies forced the enemy to make greater use of radio for shore-side coordination. These messages undoubtedly provided useful information to the Admiralty and Coastal Command who were able to deploy A/S forces more effectively. Nevertheless, at a tactical level, U-boats approaching and attacking submerged put

[476] Grove (ed.), *The Defeat of the Enemy Attack on Shipping*, Plan 4.
[477] 'Cause of U-boat Sinkings – 2nd World War,' Diagram 20 in, 'Exercise "Trident", Volume II,' CB004521, April 1949 (issued 23 January 1950), ADM 239/490.

greater emphasis on the surface escorts use of asdic. Initially, the asdic teams were inexperienced in the shallow, inshore water operations but soon efficiency improved, so that by May 1945 the escorts were sinking a very high proportion of the U-boats which tried to attack convoys.[478] As for offensive patrols, Burnett, drawing on personal experience, realised that these were protracted affairs though often crowned with success.

The Germans had realized that the schnorkel-fitted U-boats lacked the mobility necessary for operations in the open ocean. The Germans therefore, somewhat belatedly, put high priority on developing U-boats with a high submerged speed and endurance. These new types were epitomised by the 15-knot battery-driven Type XXI and the 25-knots hydrogen-peroxide, or HTP, driven Walter Type XXVI. Thinking to the future, Burnett cautioned that the results of this German research were known to the Russians and it was therefore reasonable to assume that in another war the Royal Navy would be faced with submarines built along these lines.[479] Further developments in submarine technology over the next 5-10 years presaged an increase in the maximum underwater speed and diving depth. The actual endurance that could be assumed for a particular battery-driven submarine was extremely difficult to predict for it would depend not only on the remaining charge in the battery, but also on the recent battery discharge and charging profile. Essentially, Burnett noted, their endurance at the higher speeds would be limited, so it was doubtful that the new submarines had the speed and endurance to overtake and concentrate round convoys, especially if denied supporting air reconnaissance. However, with improved homing or pattern-running torpedoes, Burnett expected them to be fired from wider angels and at ranges of five or six miles, without hitting power being diminished. Submarines could therefore stay outside the reach of normal escort stations. Consequently, if a submarine did not betray its presence, other than by the impact of its torpedoes, the area that A/S forces would have to search would be considerably larger than for wartime U-boats. For A/S vessels which did approach these submarine not only was there the problem of improved anti-escort homing torpedoes, but they might also be equipped with short-range anti-escort rockets based on the German wartime "Ursel" project under development at the end of the war.[480] Overall, it seemed that

[478] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 2.
[479] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 2.
[480] 'German Underwater Rockets,' US Naval Technical Mission in Europe, Technical Report No. 500-45, October 1945, NHB; Eberhard Rössler, *The U-boat: The Evolution and Technical History of German Submarines*, tr. Harold Erenberg (London: Arms and Armour Press, 1981), p. 145.

> The rate at which...A/S vessels will be sunk may well be several times that at which they sink submarines. It is unlikely to be less than one escort vessel per submarine sunk....[481]

The problem of diluting anti-escort counter-attacks, together with the challenge of maintaining contact and attacking submarines when close-in, meant that engagements would have to involve at least two A/S vessels, and this put additional pressure on the overall numbers of escorts. To avoid prohibitive costs and to expand numbers quickly in time of war, escorts would have to be simple and economical to build and man. This implied a small ship, which conflicted with the requirement for the A/S ships to be capable of at least 25 knots in moderate weather if they were to stand any chance of catching and attacking a fast submarine. This requirement would tend to drive up the ship's displacement, as would the growing demands of weight and space for asdic, radar and radio equipment, as well as weapons. The asdic system envisaged comprised a search set capable of detecting at longer range and with a higher rate of angular coverage, with another set capable of providing instantaneous range, bearing and depth information to the weapon system. This combination, it was hoped, would allow the ships to search at a higher rate (provided the classification and self-noise problems could also be solved), and to hold contact despite the dynamics of high-speed manoeuvres of the fast submarine and A/S ship. Sinking a submarine with an aimed weapon, would mean replacing the existing ATW with the "Limbo" mortar capable of engaging the target on any bearing and variable range, thus leaving the ship free to manoeuvre as required to keep contact. Fine resolution radar and a good Action Information Organization (AIO) system would be essential for ships to manoeuvre in close company without mutual interference or collision. The AIO would also be used to combine D/F information from a submarine's use of radio, radar or acoustic transmissions. The resultant fix could be used to target long-range A/S homing torpedoes fired from the escorts. Four Weapon class destroyers, of the Sixth Destroyer Flotilla (6DF) were being converted and would be used for trials to establish the requirements for specialized A/S destroyers. The more extensive conversion of an older destroyer, integrating the improved AIO, new asdic and A/S weapons, was being considered for inclusion in the next year's programme. If the modifications proved to be successful, there were 35 older destroyers which were thought to be suitable for this "Type 15 Frigate" modernisation {*Plate 20*}.

The high speed and long endurance of aircraft gave them an inherent advantage in patrolling large sea areas. Their high speed also made aircraft ideal for patrolling

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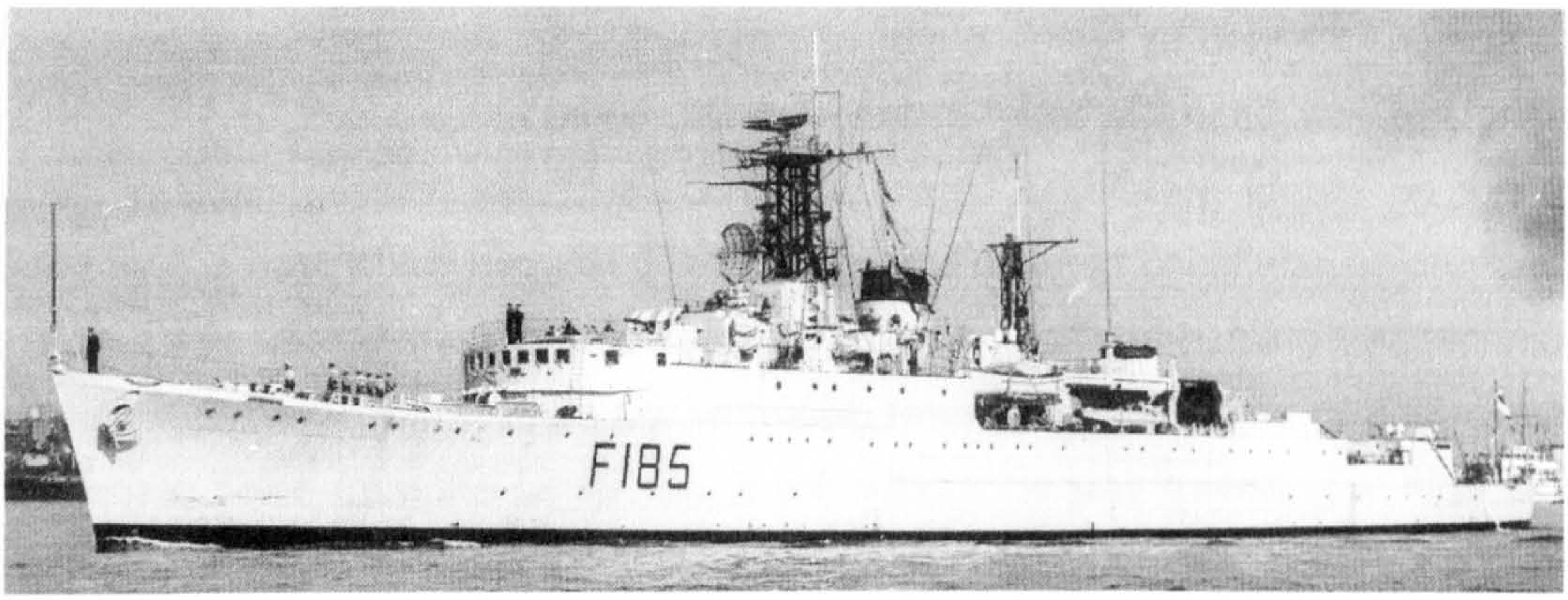
[481] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 3.

Plate 20: Type 15 Frigate – HMS *Relentless*

Leo Marriott, *Royal Navy Frigates since 1945*, 2nd edn. (London: Ian Allan, 1990), p. 37.



round convoys or quickly following up fleeting submarine contacts. This had been very valuable when U-boats relied on the surface for search and mobility. However, with modern submarines operating perpetually submerged, aircraft needed a reliable system to detect submarines when snorting, or, ideally, when fully submerged. During the war aircraft were equipped with only one weapon, the US Mk 24 homing torpedo, which could be used against a fully submerged submarine. Colloquially known as "Fido" or "Wandering Annie", the weapon homed on its target's HE, like a three-dimensional version of the Gnat. The weapon had a speed of only 12 knots and an endurance of 10 minutes. Its small (92 lb.) contact-fused warhead was designed to achieve at least "mission kill".[482] It had to be aimed accurately, ideally on the swirl created by a U-boat which had just dived, though the weapon could also be dropped on the U-boat's position derived from a sonobuoy pattern. Passive homing was technically the simplest system, but relied on low self-noise from the torpedo and (like sonobuoys) on adequate noise from the target. So, if the submarine was travelling at slow speed (less than 6-9 knots), or the torpedo travelled too fast (above 20-25 knots), the homing range would be severely compromised. Passive homing torpedoes were also vulnerable to fairly simple submarine-launched acoustic counter-measures.

An active torpedo, on the other hand, was unaffected by a submarine's noise output and less distracted by its own noise. Consequently, this form of torpedo was able to home at a higher speed and, while less susceptible to submarine-launched countermeasures, the target was also more likely to be aware of its presence. The active torpedo's performance, however, could be drastically reduced if the enemy were able to coat their submarines with a suitable anti-asdic covering, such as the German "Alberich" rubber coating. The British, unlike the Americans, were convinced that '...the homing of torpedoes will not be effective in shallow water with which they are deeply concerned.'[483] 'Owing to its comparatively narrow transducer [beam] pattern, which is necessary to achieve a reasonable homing range,' the paper continued,

> the initial location of the submarine by the torpedo presents a serious problem and this will be even more marked in the case of aircraft launched torpedoes where accurate aiming is difficult to attain. The chief difficulty likely to be experienced with active acoustic homing, especially in shallow water, is the likelihood of the weapon homing on "non-sub" echoes....[484]

Forecasts of the likely performance of homing torpedoes were uncertain. At best it was concluded that, for torpedo speeds greater than 35-40 knots, homing ranges of between 1,000 and 1,500 yards would be possible, though not '...for some years yet.'

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[482] 'Torpedo Mine Mk 24,' Bernard Stephens, 30 April 1998.
[483] 'Report of Coordinator of Undersea Warfare...,' Box 90, RG 313, NARA2, p. 2.
[484] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 4.

Under less favourable operational conditions, these ranges might easily be less than half these values. One solution suggested was the use of a human operator to guide the torpedo via a trailing wire connection. This system could be applied to aircraft if the weapon trailed the wire from a floating buoy fitted with a radio link to the aircraft. 'The main advantage of this arrangement,' the paper suggested, was

> ...that the discriminatory power of the human ear [was] retained until the last possible moment, which may permit decoys and spurious signals to be distinguished and disregarded. This method may also render possible some small increase in homing range and/or speed.[485]

The only sonobuoys in service with the British were those omni-directional types left over from wartime stock supplied by the US and these would all be expended during training and in exercises by 1949. The British were developing a new sonobuoy, based on the American design. The improvements incorporated in the design were limited to those necessary to make it compatible with the RAF and RN aircraft currently in service. Against a large modern submerged submarine at 10 knots at periscope depth, or 15 knots at 200 feet, it was calculated that the new British buoy would achieve a range of 8 miles in sea state 1. This was the maximum performance. If the submarine travelled slower, or the sea state increased, the detection range deteriorated significantly. For example, against the submarine at 10 knots at 200 feet in sea states 4-5, the range was only 1½ miles. To overcome these limitations it was theoretically possible for aircraft to carry expendable active sonobuoys, or an asdic in a body towed below the aircraft at a maximum speed of perhaps 40 knots. No research was being undertaken in Britain, but the Americans were thought to be experimenting with helicopters which would hover while deploying the asdic body. Airships, Burnett thought, offered more promise than the low-performance helicopters then available.

MAD had not been used in British aircraft, and its limited detection range meant that the swath swept during a search was very narrow, especially against a deep target. It was, therefore, only really effective against relatively shallow submarines. The British, therefore, considered its operational value confined to narrow channels and in some tactical situations. It was totally unsuitable for large area searches. The British were not carrying out any technical development of an airborne radar for long range detection of snorts, though they were closely following the results being obtained by the Americans, and were studying the operational potentialities of the method.[486] As for submarine radar or "Squash" radio transmissions, it was not yet known what equipment

[485] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 4.
[486] 'Maritime Radar for Search and Shadowing,' Sub-SAWC/II/62/48, n.d., in, 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

would be needed for an aircraft to make detections. It was thought a possibility for aircraft to home onto a submarine radar transmission, provided it was of long enough duration. Burnett was doubtful of the operational value of such equipment to aircraft, as comparable with its essential worth to ships. He then briefly examined of the use of submarines as A/S vessels. Working in the same environment as the enemy, Burnett thought A/S submarines might be less affected than surface ships by adverse environmental conditions. However, submarines employed in the A/S role would also need an asdic capable of detecting and localising enemy submarines. Even if submarines proved to be more efficient asdic platforms (compared to surface ships) the asdic would remain a short-range sensor, limiting the usefulness of submarines as A/S vessels. Moreover, the greatest hurdle was the provision of effective recognition equipment if submarines were not to be attacked by friendly forces. Nevertheless, the development of an A/S "fighter" submarine for use in co-operation with surface forces and of patrol submarines for A/S operations in enemy controlled water were under considerations.[487]

Burnett did not envisage any substantial increase in the detection range of A/S sensors in the foreseeable future. Some additional performance might be squeezed out of existing asdics by measures to quieten the ship, thus causing less interfering noise, by silencing the ship's propellers through better designs and masking techniques. Other limitations were due to the fundamental properties of sound and to the environment were extremely difficult to overcome with existing technology. These included the effects of temperature gradients, background noise and reverberations. Substantial improvement in asdic performance was only possible if lower acoustic frequencies were used, because the attenuation of the transmitted energy was less as it passed through the water. However, lower frequencies demanded a larger transducer if the transmitted was not to be dissipated over too wide an acoustic beam. Many of these issues had been investigated in the 1920s and 1930s. Design features of the submarine could also adversely affect asdic performance. For example, streamlining the hull to achieve high speed reduced the asdic echo, especially on ahead and astern aspects. Submarines could also be covered in asdic-absorbing material, similar to the "Alberich" rubber coating applied to a few U-boats during the war, which could reduce the reflected energy by about 15%.[488] A captured U-boat (*U-1105*) with this covering had been the subject of British trials in the immediate post-war period. As for asdic

[487] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 5.
[488] 'Rubber Covering of German Submarines Anti-Asdic (German code name "Alberich"),' 20 September 1945, Report No. 352-45, NavTecMisEu, Series IV, Technical Reports #351-45 thru #370-45, Box 35, OA, NHC.

listening, this method was critically reliant on the noise output of the submarine. It seemed that, with existing technology, operationally useful ranges could only be achieved against a submarine travelling at about one-third of its maximum speed, or faster, and at relatively shallow depths. Other, more novel, methods, such as wake, magnetic and electrical detection, were seen as likely to produce operational results only in the distant future.[489]

To achieve all these technical solutions the scientific effort required would be considerably in excess of that normally accorded in time of peace. Furthermore, the stock of fundamental research had been exploited during the war and now needed to be replenished. The research resources thereby diverted would diminish Britain's capacity to develop weapons and sensors.[490] The Admiralty also had to face the limitations of scientific manpower, for apart from those released to civilian projects, many departments were not affording sufficient priority to military developments, and a proportion of the remaining stock of scientists were also to be transferred to atomic work.[491] The efficient tactical use of new equipment rested on adequate training in its use, but this would always lag behind the provision of the new gear. The perception was that equipment would also be introduced into service at a slower rate in peacetime, due to '...financial stringency,' though delays were probably more to do with the sheer complexity of the new technology and a shortage of electronic engineers.[492] In addition the effective use of the new equipment would rely on the establishment of appropriate authorities '...to direct A/S operations, to analyse recent operations and intelligence and to organise and supervise A/S training.'[493]

The basic strategic assumption was that an enemy would use his submarines to attack British trade, though some units might be used for operations against the Fleet, or, with the use of rockets, against British territory, including ports. The attack on trade would be most dangerous if the enemy operated in the inshore focal areas where shipping was most concentrated. This might be supported by a relatively small number of submarines deployed on more distant operations to force the British to disperse their A/S effort and to adopt a comprehensive convoy system, which would reduce the effective volume of British shipping. If A/S measures could be concentrated in these inshore areas and achieve a sufficiently high attrition rate of enemy submarines, they

[489] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 9.
[490] 'Progress in Underwater Warfare, 1946,' ADM 239/420.
[491] Note by Sir Henry Tizard to the Minister [of Supply], 24 August 1948, DEFE 9/12; 'Research and Development Priorities: Report by the Defence Research Policy Committee,' H.T. Tizard, COS(49)220, 9 July 1949, DEFE 5/14.
[492] 'HMUDE Summary of Progress,' 1 December 1948, NAA(M): MP1049/5, 1968/2/800.
[493] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 1 [emphasis added].

might adopt a policy of directly attacking escorts (if they had not done so from the outset). As a last resort the enemy were likely to re-deploy into open ocean areas, where, still operating submerged, it would be much more difficult for them to find their targets without strong air reconnaissance – a lesson that had been graphically demonstrated by the German failure in this regard.[494] Burnett thought that a future enemy would have much greater difficulty in locating and closing in on targets, than had the U-boats in the war and the reconnaissance aircraft might prove to be vulnerable targets themselves. The enemy might also develop methods of co-ordinating attacks by submarines so as to oppose the escort of a selected convoy with a tactical concentration of submarines. Once in contact, the new submarine types would pose a much more serious menace.[495]

The A/S measures proposed bear a strong resemblance to those conceived in the Admiralty during, and formalised immediately after, the war (as covered in Chapters 3-5). The basic strategic and tactical countermeasure remained the institution of convoy, which made it harder for the enemy to find their targets and forced submarines to move if they were to close their targets (and hence expose themselves to counter-detection). The enemy's task would be made more difficult if their use of airborne reconnaissance could be curtailed and if convoys sailed at high speed. Ultimately, escorts were needed to attack submarines approaching or reaching a firing position. To reduce the number of submarines able to operate against trade, it was planned to carry out attacks on the enemy's submarine building potential (through direct bombing and indirectly through economic warfare). At least half the operational Russian submarine force was expected to be in harbour at any one time for maintenance and to rest personnel. Thus, taking into account transit times, about 15% of the total could be maintained on patrol in UK waters. Attacks on their bases and training areas were therefore envisaged, either by direct bombing, or with mines.[496] Submarines on passage or in their operational areas would also be subjected to offensive operations by A/S forces and the constant worry of defensively laid mines.

With the draft of his paper completed, Burnett was relieved in August 1947 by Captain C.E.E. Paterson, another wartime escort group commander. Paterson steered the draft though the Joint Sea/Air Warfare Committee where it was approved in spring 1948 as an accurate statement of the state of A/S warfare. Paterson also broadened the discussion in the original paper, for Burnett's object had been to consider the

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494 C.H. Waddington, *OR in World War 2: Operational Research against the U-boat* (London: Elek Science, 1973), p. 37.
495 'Anti-Submarine Problems of the Future,' AIR 20/6381, Summary and Part 1.
496 Minute, [Captain] Ashbourne, DTASW, 1 November 1946, ADM 1/20030.

present A/S measures and the avenues for research and development to counter the likely threat from potential enemy submarines. His paper had covered measures such as mining, but only skirted the wider issues of attack-at-source, that is, attacks on industry, building yards and bases. So, when Burnett's draft was discussed by the sub-committees of the SAWC, the RAF complained that it did not take sufficient account of '...what would probably be the RAF's major contribution to this form of warfare: strategic attack on factories, building yards, and bases.'[497] Paterson, took action to remedy the situation. A memorandum was issued, under ACNS's signature, in early December 1947 in which the question of "Attack-at-Source" was discussed. It recognised the contribution which could be made by bombing of the enemy's submarine support infrastructure, but concentrated on the naval contribution, which needed further detailed study. 'It is evident,' Admiral G.N. Oliver, ACNS, concluded,

> that, so long as we are unable (for lack of some novel method) to detect submerged Submarines at considerably greater ranges than are at present possible, the mere squeezing of the last ounce of usefulness out of our existing means of acoustic detection will not by itself provide a sufficient antidote to the fast Submarine of the near future. In fact, the present tendency is for the Submarine Attack to outstrip the A/S Defence. It therefore becomes necessary to cast around and to consider whether there may not be other ways, as yet not fully exploited, of contributing to the defeat of the U-boat.[498]

Although the enemy's submarine industry and building yards were more susceptible to attacks by air, there was also a contribution that could be made by the Royal Navy by attacks on harbours in "Special Operations" using "sneak" craft (i.e. midget submarines), saboteurs and Naval cutting-out operations, just has had been done on numerous occasions during the war. In addition, investigation into these methods would enhance British countermeasures against their use by the enemy. The key was that these operations were seen '...as components of the whole A/S problem.'[499]

Submarine Tactical and Technical Development

By the end of 1947 DTASW produced two further papers. One reviewed past enemy submarine tactics and assessing their future progression, and the other paper examined submarine technical developments. Both papers reviewed wartime submersible operations some detail, since this type was still in use by the post-war

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[497] 'Minutes of the Seventh Meeting of the Policy and Plans Sub-Committee held in the Admiralty on 7 November 1947, Sub-SAWC 1/14/47, 13 November 1947, AIR 20/10176.
[498] 'A/S Problems of the Future – Attack-at-Source and Harbour Defence,' G.N. Oliver, Office of the Chief of Naval Staff, 8 December 1947, ADM 1/21546.
[499] Minute, G.N. Oliver, 8 December 1947, ADM 1/21546; Minute, D of P, 17 December 1947, ADM 1/21546; 'Small Battle Units,' DTASW, TASW.4037/48, April 1948, DEFE 2/1660; Richard H. Allen, 'The Attack-at-Source and the Development of the British X-Craft Midget Submarine, 1945-1958' (MA, London, King's College, 2000).

Russian Navy. Schnorkel-fitted submersibles and the Type XXI (now designated "Intermediate (B)") were also described. As for the Walter Type XXVI boats, now styled "Intermediate" submarines, none of these had been completed.[500] The Intermediate (B) emphasised submerged mobility. She could sustain speeds of 16 knots for an hour, or 20 knots in short bursts. At 15 knots, the battery was only half discharged after an hour, leaving plenty of power for manoeuvring at slower speeds.[501] At medium speeds the Intermediate (B)'s endurance was impressive compared to earlier types. It could maintain 12 knots for 4 hours, 8 knots for 10 hours, or 4 knots for 4 days. The snorting speed was about 10 knots and, under ideal conditions, could be as much as 15 knots, though vibration (and thus periscope vision) was likely to be a problem.[502] In principle, the Intermediate (B) could avoid searching A/S vessels, though its use of high speed might betray its presence at long range, or confirm a doubtful contact for an escort. With its long endurance at medium speeds the Intermediate (B) could close a high proportion of its targets. Greatly decreased reloading times meant that a series of salvoes could be fired in rapid succession. What was more, the increased performance of modern torpedoes, meant that firing ranges were, perhaps, increased by as much as three-fold. The chances of hitting would be maintained by improved fire-control, with periscope radar and the use of homing and pattern-running. This made the Intermediate (B) dangerous enough, but if they could also operate in packs, both to improve their chances of locating convoys and to make coordinated, albeit unsynchronised, attacks, the situation would become very difficult for A/S forces. Provided it was already at high speed the Intermediate (B) would be able to avoid A/S attacks, though, if travelling at slow speed, it did not have the acceleration to escape an attack pattern.[503]

The Intermediate submarine promised underwater speeds of up to 25 knots for five hours. However, these submarines were expensive to run, and their overall performance was unremarkable, except during the bursts of high speed. Moreover, because of the time taken to accelerate and slow down from its high speed (at which it would be practically visually blind and acoustically deaf), the Intermediate submarine would have little advantage over the Intermediate (B), although it might close from much greater distances on specific intelligence reports. Its great advantage was the

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[500] For the nomenclature of submarines at this period see Appendix 9.
[501] This was a slight improvement over the Type XXI performance, see Appendix 7.
[502] Eberhard Rössler, *The U-boat: The Evolution and Technical History of German Submarines*, tr. Harold Erenberg (London: Arms and Armour Press, 1981), pp. 204 and 273-274; Ships' Cover 746/A, Super-*Seraph* (*Scotsman*), Folio 4, NMM(W).
[503] 'A Review of Past Submarine Tactics and a Forecast of Probable Future Enemy Submarine Tactics,' DTASW, TASW.329/47, June 1948, ADM 1/30840, pp. 7-8.

ability to outrun A/S escorts after an attack, especially if the sea was rough. As for the "True Submarine" very little was known of its characteristics, other than it was likely to be a large vessel and nuclear powered. Its high speed endurance was likely to be about 30 knots for six months, enough, the Admiralty noted, to circumnavigate round the world six times! However, to counter these submarines the Admiralty noted that '...no startling advances in its detection equipment are foreseen at present.'[504] The Admiralty had come to the view, therefore, that although there had been advances in A/S measures and weapons, these tended to lag behind the parallel increase in the offensive power of the future submarine. Since it appeared likely a future enemy could produce submarines similar in performance to the German Type XXI U-boats within the next five years, and before new A/S equipment was available, there was

> ...an urgent requirement to establish the best tactics to employ against these submarines with existing equipment, and whether any modifications to the latest A/S Vessels' equipment...are essential.[505]

The JASS View of Defensive and Offensive Operations

During the spring of 1947 the Joint Anti-Submarine School (JASS) at Londonderry were teaching tactics that were heavily based on the methods of the last war, modified to cope with the 15-knot submarine. No revolutionary changes had been made in these tactics, and none were expected in the near future. During the war it had been impossible to defend a convoy solely with surface escorts because there were never enough A/S ships to form a continuous asdic screen. Defence in depth was found necessary, with aircraft in the deep field, surface support groups at 15-20 miles and finally the close escort in the immediate vicinity of the convoy. Even if the outer forces were not able to sink U-boats detected, the warning provided the likely direction of approach and allowed the close escort (and support groups) time to form a local concentration against subsequent attacks. These cues were also combined with intelligence from HF/DF bearings of enemy transmissions, as well as tactical estimates of likely approach directions based on the prevailing weather conditions and operational experience. Ultimately, the torpedoing of a ship could be used to indicate the likely position of the firing U-boat.[506]

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504 'A Review of Past Submarine Tactics...,' ADM 1/30840, p. 8.
505 'Progress in Tactics: 1947,' ADM 239/143, pp. 11-13.
506 'Joint A/S Warfare – Convoy Defence and Offensive Operations – A General Outline Lecture,' Lieutenant Commander D.E.B. Field, RN, Wing Commander H.A.S. Disney, RAF, Commander A.W.F. Sutton, RN, Joint A/S School, Londonderry, Issued 28 May 1947, Revised 27 October 1947, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 1.

However, since the development of the Type XXI, now referred to as the Intermediate (B) submarine, a number of new factors needed to be considered.[507] Firstly, aircraft and surface support forces were unlikely to detect submarines which approached submerged, even when using their schnorkel. It was also assessed that submarines would use of the "Squash" (or burst radio transmission) technology. Because these signals could not be intercepted at sea with existing technology, A/S ships would no longer be alerted by submarine sighting reports. As an alternative, JASS suggested the use of smoke or foxers to force submarines to transmit on radar to locate their target, and thereby betray its presence before attacking. Furthermore, an Intermediate (B) armed with long-range torpedoes, could fire from outside existing screens. With the capability to rapidly reload, these submarine could fire 18 torpedoes in the space of 25 minutes. With its higher manoeuvrability, the modern submarine could also get under a convoy and remain there while it fired several salvoes. The most strenuous effort would be needed to winkle out a "sub-convoy" submarine, for asdic conditions were bound to be difficult owing to the presence of the merchant ships. Optimistically, JASS wondered if the new "Four Square" (which became the Type 170) asdic might solve the problem, because it would be capable of the simultaneous measurement of the range, bearing and depth of a submarine target.[508] When a submarine was known to be under the convoy, an emergency turn could, it was thought, expose the submarine and thereby allow the escorts an opportunity to attack. However, the A/S vessels would also be tactically hampered by the risk of collision, especially at night, until the submarine moved clear of the convoy. It was best, therefore, if the submarine could be prevented from getting close to the convoy. The principle of defence in depth now had to be applied to the close screen itself and the screening ships had to be stationed further out from the convoy, which would give the escort the chance to concentrate at least two A/S ships and then more room to engage the submarine.[509] Close co-ordination between all the escort forces was needed to exploit the fleeting opportunities to destroy attacking submarines. Overall it was unacceptable to rely upon a torpedoing as a warning of an attack, for too many ships could be hit before A/S countermeasures could be started. Taking these factors

[507] See Appendix 9. 'Trade Protection – Defence of Ocean Convoys,' Group Captain W.E. Oulton, Director (RAF) and Captain R.G. Onslow, Director (RN), Joint A/S School, Londonderry, No. 725, 25 February 1948, Box 102, RG 313, NARA2.
[508] 'The Experimental Four Square Asdic Set,' HMA/SEE, Fairlie, Internal Report No. 230, 9 November 1945, ADM 259/429, p. 2.
[509] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 2.

together, JASS concluded that the submarine ought to be destroyed if at all possible before it fired at the convoy.

With all the difficulties that the modern Intermediate (B) type of submarine posed for A/S forces, it too suffered from some limitations. By operating submerged their search capability was restricted and they were best employed in focal shipping areas were targets were more concentrated. This was, however, where A/S forces were likely to be strongest. Although the Intermediate (B)'s underwater endurance was greatly improved over the wartime U-boats, it was still limited, which meant that A/S actions would be short if the submarine was operated continuously at high speed. Like the wartime snort-fitted submersibles, the Intermediate (B) could not travel at high speed when schnorkelling and was, therefore, unable to make as much ground at a U-boat capable of surface travel. The free use of the surface by submarines had been ended by A/S aircraft. In their lectures, JASS explored the capabilities and roles of A/S aircraft in some detail. Submarines by using their own radar would normally detect approaching aircraft before they could attack, as had been shown by intensive trials with HM Submarine *Viking* during the war.[510] With existing weapons an aircraft had a reasonable chance of sinking a U-boat if it could attack when the submarine was still on the surface, or at most 30 seconds after it had crash dived. Once the submarine was submerged the only means of detection was with a sonobuoy pattern. These could be used to locate a submarine whose position was already known with reasonable certainty, such as would be gained from the swirl in the water after it had dived or from a schnorkel sighting. JASS reminded its students that sonobuoys were not suitable for searching large areas and, furthermore, A/S aircraft had no reliable method of detecting a snort other than visually. However, JASS staff pointed out that:

> Submarine limitations are such that the majority of submarines taking part in an attack cannot be placed well ahead on the convoy's track. A certain amount of submarine movement is therefore necessary. Owing to limitations of snorting speed, some of this movement may take place on the surface.[511]

Of course, submarines transiting on the surface presented ideal targets for aircraft and ones which could be subjected to lethal attack or at least forced to dive and thereby probably miss intercepting the convoy. This was an observation of crucial importance in another sense. This passage highlights the vulnerability of submarines

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[510] 'Report by RAF Observer in HMS Viking during period 24 April – 6 May 1944,' HQ No. 19 Group, 30 May 1944, AIR 15/557; 'The RAF in Maritime War, Vol. IV: The Atlantic and Home Waters, The Offensive Phase, February 1943 – May 1944,' (First Draft) n.d., AIR 41/48, pp. 477-488 and 488fn1.
[511] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 4.

when forced to move. While the near stationary U-boat, especially in shallow waters, was extremely difficult to detect, submarines on the move sooner or later would expose some part of their structure above water, or make significant noise underwater. Either case gave A/S forces opportunities to locate the enemy. JASS concluded that the value of aircraft in the A/S battle was, by their sheer presence, to deny the submarines the free use of the surface and to attack any unwary submarine caught on the surface. Aircraft could also detect submarines travelling at relatively shallow depth and at high speed by using sonobuoys. Thus, relative to a convoy, the A/S aircraft should be used to provide patrols on the convoy's bows where they might catch submarines on the surface trying to close the convoy's track. They should also conduct patrols closer astern to detect submarines trying to overtake the convoy.

Notwithstanding the technical limitations of aircraft equipment, these air patrols on the bows of the convoy could be supplemented by "sono-barriers", consisting of lines of sonobuoys laid primarily by Coastal Command aircraft to detect snorting submarines closing the convoy's track. The same idea could be used astern of the convoy to catch shadowing or overtaking submarines. Lack of equipment consigned practically all the tactical experiments into the use of sonobuoys to theoretical games on the tactical tables ashore. The first buoys were placed about 6 miles ahead of the convoy and 10 miles outside the wing columns. Subsequent buoys were laid to create a barrier that stretched some 30 miles ahead of the convoy. More work was needed to investigate what was the best angle to lay the barrier relative to the convoy's mean line of advance (MLA) but the first games laid the barriers parallel to the MLA. The alternative tactics was against the shadowing submarine, when the sonobuoys were laid at right angles to the MLA of the convoy in a line extending to 10 miles outside the wing columns. There was one case of an actual sonobuoy barrier being laid during a 1947 A/S exercise where a submarine was detected and subsequently attacked.[512]

If contact was gained on a sonobuoy pattern, the aircraft was to maintain contact by laying additional buoys. Surface escorts might then be detached from the close escort to hunt for the submarine and destroy it. Meanwhile additional, carrier-based aircraft could be employed on searches ahead of the convoy.[513] These searches were aimed at deterring a submarines lying in wait from freely using its periscopes or radar. Of course, slow-moving, submerged submarines which assumed that they were directly ahead of the convoy were practically immune from detection by A/S aircraft and

[512] 'Progress in Tactics, 1948,' ADM 239/144, p. 6.
[513] 'An Outline of the Conduct of Naval Air A/S Operations in Defence of Trade,' Acting Commander A.W.F. Sutton, RN, Joint A/S School, Londonderry, 15 September 1947, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, pp. 3-4.

countering them rested squarely with the close surface escort. If any of these air patrols and searches detected a concentration of submarines, the aircraft could hold them down to limit their mobility, while the convoy carried out an evasive turn. It was seen as especially important to shake off a shadowing submarine before it could home other enemies onto the convoy. If these measures failed and there was an attack on the convoy some indication of the position of the attacking submarines might be gained, and the escort then had the opportunity to counter-attack using an intensive air and sea hunt. The weaknesses of individual A/S units meant that a combination of all available air and sea assets was vital to narrow the probability area to be searched and to try to retain the initiative. Perhaps the most difficult submarine to counter was one that had penetrated the close screen and was sheltering underneath the convoy.[514]

Clearly, large numbers of aircraft would be needed to fulfil such a concept of operations and it would not be possible for all convoys to routinely be given this high level of air escort. The policy, therefore reflected the provision of surface escorts and gave each convoy only a light through escort, which could be reinforced in danger areas by support groups. Most A/S aircraft would be used on independent area patrols over focal areas or areas of assumed submarine concentrations, and would be available to reinforce threatened convoys. Once co-operating with the convoy's escort, all aircraft should be under the tactical control of the escort's Senior Officer, who would have the best understanding of the tactical picture.[515] This tactical control, the JASS Staff taught, might best be conducted through a carrier if one was present with the escort. The philosophy was not finally determined, for at the Third A/S Tactical Liaison Meeting in May 1947 the JASS representative, while stating the clear need for an undivided command of A/S assets round a convoy, thought that '...no firm opinion had been formed as to whether this should be the Senior Officer of the Escort or the Aircraft Carrier providing the air cover.'[516]

The tactical disadvantage of the escorts also suggested that a strategic offensive would have to be undertaken against submarine construction facilities, training areas, and bases. Indeed, JASS thought this was '...probably the best means of defence.'

[514] 'RAF Staff College: Précis of Lecture on Surface Tactics,' Lieutenant Commander D.E.B. Field, RN, Joint A/S School, Londonderry, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.
[515] 'Précis: Command and Control of Joint A/S Operations,' Wing Commander H.A.S. Disney, RAF, n.d., File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.
[516] 'Third A/S Tactical Liaison Meeting held in HMS *Vernon* on 1st and 2nd May 1947,' A.198/3/47, 17 May 1947, distributed by Op-32-F-45, n.d., Box 102, RG 313, NARA2, pp. 22-23.

However, this countermeasure was '...rarely possible in the early stages of a war.'[517] The Naval Staff had long held the idea that a bombing campaign against U-boat bases to prevent submarines from putting to sea, was an important A/S measure.[518] What was more important, a bombing campaign took some time to have an impact on front line forces because of the long work-up time needed to train an operational submarine crew. Hence U-boats destroyed in their bases or being built in the factories would not have become operational for say 6 months, as DNOR had pointed out during the war when faced with the same question. As for the future, when improved sonobuoys became available their tactical use would demand close co-operation between ships and aircraft. Furthermore, the JASS Staff emphasized that A/S aircraft needed a means of attacking fully submerged submarines. The idea of using helicopters with towed asdic was already being considered by the Admiralty, though Ormsby had noted that this method had been omitted in DPR's review of airborne acoustic detection. There was, of course, no suitable helicopter available in mid-1947, but it had been decided that some investigation should be continued in tactical games at *Osprey* and JASS. It was soon concluded that the use

> ...of helicopters or blimps with towed asdic would be of greatest value in providing fast escorts with the advantages [of] aircraft to combat the fast submarine.[519]

About a third of the JASS general outline lecture dealing with joint A/S warfare was devoted to hunting operations. 'The principle of the offensive,' the staff asserted, 'applies to anti-submarine warfare as it does to other forms of warfare.'[520] However, just as with the direct defence of convoys, the improved performance of the Intermediate (B) submarines made offensive operations more difficult. This meant, JASS Staff affirmed, that sea and air forces had to be highly trained to take advantage of any opportunities that occur from their operations or the mistakes by the enemy. The forces available for these operations were shore-based, long-range aircraft, fast A/S destroyers and frigates, and escort carrier hunting groups (though none of these were in the naval force planning). The latter might, ideally, consist of two CVE's (one of which, depending on the area of operations, might carry a complement of fighter aircraft). The CVE's were provided with a close escort of four A/S ships and an

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[517] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 3.
[518] 'Remarks on Air Staff Paper on the Employment of Heavy Bomber Force against Enemy U-boat Organisation.' [covered by First Lord's note, 15 December 1944], PREM 3/414/1.
[519] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 5; 'Minutes of the 4th Meeting of the Technical Investigation Sub-Committee, 8 August 1946,' Sub-SAWC/III/7/46, 12 August 1946, ADM 116/5614.
[520] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 6.

additional "striking force" of 5-6 more A/S ships. If the direction of the enemy was known, striking force would operate 10-30 miles ahead of the carrier and her close escort, depending on whether radio silence was in force or not. Aircraft would fly intensive patrols on either flank of the force, or a search down HF/DF bearings. Otherwise the close escort and the striking force would all be stationed in a ring about the carrier, with the A/S ships operating in pairs for mutual support. The aircraft would also search all round the force, using a "step-aside diverging" search. These operations would be supplemented by shore-based aircraft patrols within boxes ahead of the force's track to allow the aircraft to maintain regular observation of the area, and presumably re-visiting each part of the area frequently enough to have a reasonable chance of detecting a snorting submarine.

The depth of all these air searches was dependent on the ability of an aircraft to hold a submarine contact for long enough to allow the striking force to arrive with a reasonable chance of regaining the contact. Shore-based aircraft, with larger crews and stocks of sonobuoys were better able to hold contact for longer. The A/S vessels of the striking force needed to have a minimum speed of 25 knots and a good endurance. This meant that taking into account the time current sonobuoy types could maintain contact and the chance of a surface striking force locating the submarine, air searches were to be limited to 2-2½ hours steaming from the striking force, say 50-60 miles.[521] At first sight, this distance seems rather ambitious, given the long endurance of the Intermediate (B) submarine at moderate speeds, continuing slow asdic search rate and earlier ideas on the matter.[522] In the two hours a surface group might take to arrive at the datum, the submarine could be anywhere in an area of, say, 1,800 square miles. However, it was hoped that the aircraft could maintain sonobuoy contact for the striking force, as the JASS staff pointed out, to have a "warm scent" and therefore only have to search a relatively small area.[523] More intensive hunts would be conducted by a carrier group using her aircraft and supporting surface striking force, especially when positive indication of a submarine was given, say, by an attack on a convoy. Carrier hunting forces could also be used to seek out supply submarines or ones acting as a Loran radio fixing station. The greatest danger in using carriers in this role was the risk that they would be sunk, especially when employed against fast submarines. Over the following months the USN worries on this point increased, because '...in all recent

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[521] 'An Outline of the Conduct of Naval Air A/S Operations in Defence of Trade,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 6; 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 7.
[522] See Chapter 1.
[523] 'RAF Staff College: Précis of Lecture on Surface Tactics,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

exercises [fast] Guppy submarines have penetrated the screens and torpedoed the carriers.'[524]

Land-based aircraft on independent operations would fly either square searches or creeping line ahead patrols, whereas carrier-borne aircraft would normally be used in daylight on radial searches from the carrier, or in relative searches on the beams of the surface striking force.[525] It was hoped that the aircraft would obtain an initial sighting. This would be reported immediately to the ships via a "Flash" radio message, and the aircraft would then carry out an urgent attack. If contact was lost, or, the attack failed, the aircraft would then remain in the vicinity of the submarine (or datum) and home the ships. If possible, contact would be maintained by the aircraft using sonobuoys in which case the aircraft would remain in tactical control of the situation until the ships were able to gain firm contact. Tactical control would then be ceded to the Senior Officer of the A/S ships. Of course, the aircraft would only be able to maintain sonobuoy contact if the submarine was trying to evade at high speed. If, on the other hand, the enemy tried to escape at sub-cavitation speed, the submarine would not have travelled far by the time the escorts began their asdic search. A major weakness in these tactics was the lack of a homing weapon with which aircraft could attack fleeting contacts, or submerged submarines being tracked on sonobuoy data. British progress with A/S homing torpedoes was painfully slow and the final requirements these weapons had not been laid down, as HM Underwater Detection Establishment, Portland (HMUDE) reported. In fact, a considerable amount of preliminary investigation and experiment was still to be done.[526] In the meantime A/S aircraft were armed with a 250 lb A/S depth-charge which could not be used against submarines deeper than schnorkel depth.[527] Improvements, too, were needed in the sonobuoys themselves to increase the chances of aircraft gaining and maintaining contact on submerged submarines, in a wider variety of circumstances.

These air and sea operations, mainly in focal areas or on submarine transit routes, were primarily designed to limit the enemy's strategic and tactical mobility by forcing them to remain submerged and use their snort. 'This,' it was hoped, 'will have the effect of reducing concentrations in operational areas and the weight of attack on

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[524] Admiral R. McGrigor, Commander-in-Chief, Home Fleet to Admiral of the Fleet Lord Fraser of North Cape, First Sea Lord, 24 November 1948, Section 5, ADM 205/70.
[525] 'Part IV – The Control and Operations of Aircraft and Surface Vessels in a CVE, April 1945,' in, 'Naval Air Anti-U-Boat Instructions (Short Title: NAUI's),' AWD 650/45, CB04405 (G.B.), Naval Air Warfare and Flying Training Division, April 1945, Box 147, RG 38, NARA2.
[526] 'The Asdic and its Associated Weapons,' DERA, AN.15971, p. 18.
[527] 'RAF Staff College: Précis of Lecture on Anti-Submarine Tactics – Shore Based Aircraft,' Wing Commander H.A.S. Disney, RAF, Instruction Office, Joint A/S School, Londonderry, 12 September 1947, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

individual convoys.' This seems an expensive allocation of assets for such an ill defined result, though as JASS pointed out, advantage would be '...taken of any opportunities to take offensive action against the enemy.'[528] Such opportunities were likely to be few and far between, unless the enemy was either careless, or under pressure to achieve high speed transits to reach their operational areas. By October 1947 Captain R.G. Onslow and Group Captain W.E. Oulton, the Directors of the Joint Anti-Submarine School at Londonderry, submitted a detailed paper on the defence of ocean convoys. The paper was produced to fulfil the remit suggested by DTASW and D of Ops in their paper of July 1946 and subsequently discussed at the Fourth Meeting of the Tactical and Training Sub-Committee of the Sea/Air Warfare Committee on 18 July 1946.[529] The JASS paper dealt only with the "short-term" problem. It drew on sea exercises and tactical table investigations that had been undertaken at Londonderry over the previous 18 months, as well as comments from Headquarters, Coastal Command.[530]

At the outset, JASS noted that it was unlikely that the failure of the Germans to develop submarine-air co-operation would be lost on the Russians. Although considerable investigation of reconnaissance problems remained to be done, it seemed that enemy aircraft ought to be able to provide a reasonable picture of shipping movements which the enemy could use to home his submarines onto their targets. If appeared, therefore, that the value of evasive routeing of convoys would be limited. This would be

> ...of particular tactical importance if heavy A/S countermeasures had succeeded in driving the submarine patrols away from the focal points into areas of less shipping density.[531]

Although, the margin of speed of the fighters over the shadowing aircraft was likely to be small, until the sonic barrier was passed with the advent of jet fighters, JASS assessed that the reconnaissance aircraft might have some difficulty in shadowing in the face of fighter cover, at least by day. This was particularly the case if the fighters

[528] 'Convoy Defence and Offensive Operations...Lecture,' File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC, p. 6.
[529] 'Minutes of the Fourth Meeting of the Tactical and Training Sub-Committee...,' ADM 116/5614; 'Trade Protection – Defence of Ocean Convoys (73/JAS/RAF/S.100/AIR), Wing Commander C.B. Gavin-Robinson, RAF, and Commander J.W. Hale, RN, Sub.SAWC/II/36/48, 18 February 1948, Box 102, RG 313, NARA2.
[530] Reference Sheet, 'Defence of Fleet Units against Submarine Attack,' C.E.E. Paterson for DTASW, TASW.380/48, 19 August 1948, AIR 2/5950; 'Trade Protection – Defence of Ocean Convoys,' Box 102, RG 313, NARA2.
[531] 'Trade Protection – Defence of Ocean Convoys,' Group Captain W.E. Oulton, Director (RAF) and Captain R.G. Onslow, Director (RN), Joint A/S School, Londonderry, No. 73/JAS/RAF/S.100/AIR, 17 October 1947, Box 102, RG 313, NARA2, p. 1.

were well directed from the force protecting the convoy, as had been amply demonstrated during battles around Mediterranean convoys.[532] To make best use of the location of convoys from their reconnaissance aircraft, it seemed that it was best to dispose the submarines in depth to the greatest extent possible, consistent with adequate breadth across the convoy's track to give a good chance of gaining a detection.

If interceptions were to be successful, the submarines would have to be equipped with accurate navigation systems. They would, however, make least possible use of radio transmissions, in order to preserve the element of surprise. When transmission was necessary they were likely to make use of the German "Squash" burst-transmission communications system, with their messages re-broadcast from ashore for the benefit for all other submarines. Once a submarine made contact the remainder could either attack as they came into contact, or some attempt could be made to co-ordinate the attack by the pack. These attacks would not be simultaneous, however, until the advent of the higher performance Walter-powered submarines which were expected to have improved sensors and equipment for inter-communication. A proportion of the initial attacks might be deliberately directed at the escort. For individual attacks submarines could fire their first salvo from outside the escort screen, probably using pattern-running torpedoes, or from closer inside the escorts. In the latter case, they were likely to attempt to penetrate the screen at slow speed, using normal anti-asdic tactics. The second salvo was likely to be fired at close range, and the third from beneath the convoy. The submarine's high speed capability would probably only be reserved for evasion when detected, or when closing from an unfavourable position. The JASS paper did not deal with offensive search, but they assumed that

> ...the broad principle will be adopted for having a heavy scale of independent air patrols reinforced by the surface forces in the focal areas, their objective being to drive the submarines into areas of less shipping density or, at least, to prevent the enemy using pack tactics in the focal areas.[533]

JASS also made passing reference to the possibility of using submarines in the anti-submarine role for offensive operations. The main direct protection of convoys, however, was expected to be provided by "through" surface escort of eight ships, which would be reinforced by at least four more, as the convoy passed through danger areas. As far as possible, the surface escort should be stationed to maximise the chance of asdic contact (since no other warning was likely) and deployed in depth to give sea

[532] M. Llewellyn-Jones, 'Preface,' in, *The Royal Navy and the Mediterranean Convoys to Malta in World War Two* (London: Cass, forthcoming).
[533] 'Trade Protection – Defence of Ocean Convoys,' Box 102, RG 313, NARA2, Part II.

room for a counter-attack before the submarine could fire. A/S ships would have to be constantly aware of the threat of being the target of anti-escort torpedoes. The overall coverage of the escort diagram would have to take account of the wide relative bearings from which the fast submarines could approach. During the periods of higher danger the convoys would also receive light air cover from shore-based or carrier-borne aircraft (with the carrier stationed within the convoy or some 10-15 miles distant). JASS considered that the balance of air effort should be employed on independent patrols in the submarine probability areas, where they would also be available to reinforce directly threatened convoys, though there was little the aircraft could do to support surface vessels, once the submarines were at close quarters with the convoy. The convoys, considering the threat from enemy aircraft, also needed to be provided with fighter cover. The multiplicity of A/S assets and the need to respond immediately to fleeting contacts of fast submarines, emphasized the importance of team-work and the efficient use ships' AIOs. These demands in no way detracted from the need for individual ships to act aggressively and on their own initiative. This recipe would have seemed very familiar to wartime escort group Senior Officers.

The Third and Fourth Escort Flotillas

Much of the impetus in developing the broad range of A/S measures was that individual methods were ineffective. The advent of the fast submarine had made it ever more difficult to locate and destroy the enemy with any certainty. These views, well-founded though they proved to be, were largely theoretical in the immediate aftermath of the war, because of the lack of high-speed targets against which to assess the actual performance of existing A/S equipment and tactics. During the spring of 1946 there were a short series of A/S exercises involving the Home Fleet and, although no fast submarines were yet available, some elements of the A/S problems could be explored. A large number of submarines were employed and they had support from aircraft in locating their target, though communications difficulties limited their value. Even so, many attacks were made on the Fleet, simulating long-range torpedo fire at about 6,500 yards from outside the normal A/S screen. The analysis of the exercise noted that if fast submarines were to approach at high speed from the bow or beam and fire at these long ranges, then the traditional A/S screen would have to be extended, to cover a wider arc and at a greater distance from the main force. This meant that the escorts would be stationed further apart and, with the high relative closing speed, the asdic coverage of the screen would be at an absolute minimum.

This could only be solved if more A/S vessels were made available.[534] This was a conundrum which would beset the Admiralty for some time. What to do when one of the escorts gained contact was, however, a more tractable problem.

The potential for high speed evasion by a modern submarine meant that accurate and up-to-date tactical information was vital if the submarine's manoeuvres were to be quickly appreciated. Thus an effective hunt relied on co-operation between the ships, and especially on a close understanding between the ships' Commanding Officers. This implied a good AIO and faultless inter-ship communications, so that both ships kept abreast of the highly dynamic engagement of a 15-knot submarine. The asdic data rate was slow and so it was not possible to rely solely on the plot to give adequate warning of changes in the submarine's movements. The plot was helpful for identifying the best disposition of the hunting team and planning lost contact procedures, but had to be combined with the more immediate direct asdic information of changes in doppler, or HE, in order to plan individual attacks to best advantage. This meant that the asdic operators had to be constantly alert, though their task was not made any easier by the interference from the unifoxer, streamed for the ship's protection.

In the wake of the trials with the 12-knot *Seraph* in the autumn of 1944 DASW had concluded that the existing pair ship tactics remained effective against a fast U-boat.[535] This idea was carried forward into the immediate post-war period. A single ship ran a high risk of losing contact, while a third ship could be an embarrassment during highly dynamic engagements at relatively short ranges. Even against slow-moving U-boats a succession of attacks were often needed to ensure destruction. Therefore, two ships should co-operate during the close A/S action, one to attack and the other to concentrate on maintaining contact. These ships were stationed 90° apart on either quarter of the submarine, which meant that they were less likely to physically obstruct each other or cause acoustic interference. Also the submarine was normally beam-on to one of the ships (thus giving the strongest echo), and they were ideally placed to make use of HE bearings to fix the submarine. These tactics seemed fairly robust against 12-knot target, but there was doubt whether they could cope with a faster submarine.[536]

Post war thinking recognised that the most difficult part of an A/S hunt was gaining initial contact and then its classification. Once in firm contact, the problem was

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[534] 'Progress in Underwater Warfare, 1946,' ADM 239/420, p. 34.
[535] 'Minutes of the First Meeting of DASW's Sub-Committee of ACNS(UT)'s U-boat Warfare Committee held at the Admiralty on Thursday, 30 November 1944, (Copy)' Folder NSS 1271-22, Vol. 8080, RG 24, NAC.
[536] 'Progress in Tactics: 1947,' ADM 239/143, pp. 21-22.

to maintain that contact. The wartime two-ship close A/S action tactic, however, meant that '...the additional ships are not employed to the best advantage' because they were held clear of the submarine and could not contribute to maintaining asdic contact.[537] The more ships that could get into asdic contact, it was felt by 1947, the greater chance there was of at least one ship holding contact on a fast submarine. It was with this idea in mind that the concept of a "Ring" formation around a submarine had been developed by the Fourth Escort Flotilla (4EF) in early 1947. It was designed as a '...co-ordinated scheme of A/S action by four or more ships, against the fast U-boat.'[538] During the latter part of 1947 the Third Escort Flotilla (3EF), based at Portland and responsible for tactical investigations, developed the idea further. Such development work was made problematic, because the 3EF ships' operations rooms were equipped with inferior Action Information Organization (AIO) facilities, making the control of dynamic tactical evolutions more difficult.[539] The idea of the "Ring" was to place all available A/S vessels within asdic range of the submarine. The first ship to gain contact was designated the "Attacking Ship" and attacked immediately. As other supporting ships arrived, they were disposed '...equidistantly apart on the perimeter of an imaginary circle, the centre of which is the submarine,' and whose diameter was between one and two miles, depending on the prevailing asdic conditions. The ships were then manoeuvred by the Senior Officer roughly to conform with the course and speed of the submarine, so that the submarine was always in the centre of the ring. Individual ships would make minor adjustments to maintain themselves in their correct station from the Senior Officer. The Attacking Ship would continue to attack until the submarine was destroyed, or she lost contact when she would take a station on the ring, and one of the supporting ships already in asdic contact would take over the duties of the Attacking Ship. It was thus possible to ensure that continuous attacks could be maintained. The theoretical advantage of this tactic was that, by surrounding the target, at least one of the A/S ships was well placed to take over the attack if the submarine took violent evasive action. The key was for all the ships to keep an accurate tactical plot of the other ships in the action and the position of the submarine, which was continuously reported by the nominated "Asdic Plot Control Ship". Manoeuvring the ring also relied on strict R/T discipline amongst the ships to avoid confusion and maintain good communications. This level of positive direction was unnecessary if individual ships were able to hold the

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[537] 'Progress in Underwater Warfare, 1947,' DTASW, TASW.116/48, CB04050(47), 8 October 1948, ADM 239/421, p. 33.
[538] 'Third A/S Tactical Liaison Meeting held in HMS *Vernon* on 1st and 2nd May 1947,' A.198/3/47, 17 May 1947, distributed by Op-32-F-45, n.d., Box 102, RG 313, NARA2, p. 22.
[539] 'Progress in Tactics, 1948,' ADM 239/144, p. 28; and more particularly, 'Progress in Underwater Warfare, 1947,' ADM 239/421, p. 33.

"Ring" formation by maintaining formation on the submarine's position. Early experience, however, showed that close control was '...more suitable for ships with little experience and those who have not worked together as a group.'[540]

3EF's trials reached only tentative conclusions because these preliminary trials had been limited due to other commitments. They had barely touched on the fringe of the problem, and there were a number of outstanding questions, which, it was hoped would be tackled by further trials at sea by Fleet units or those attached to the training schools. Nevertheless, it seemed that the most efficient number of A/S vessels was four or five disposed on a circle of 1,500 yards radius. Any more ships and the formation became unwieldy. Overall, it was considered '...that this type of A/S action is perfectly feasible provided ships have reasonable AIO facilities,' and 'given reasonably good operating conditions it is not difficult to keep the submarine inside the ring.' Indeed, contact keeping was easier when the submarine was going fast because the hydrophone effect and pronounced doppler were a great aid. If contact was lost, the ships in the ring by carrying out an all-round HE sweep followed by an all-round asdic search, could, it was hoped, regain contact. The ring tactic had, however, only been tried against the fast "S" Class boats, since no Intermediate (B) submarines were yet available. The Admiralty concluded that these preliminary trials

> ...indicate that this method of A/S action has distinct possibilities in competing successfully with the Intermediate (B) submarine. It is considered too that this method possesses certain advantages over the more conventional two ship action – the chief of these being the reduced likelihood of contact being lost once the submarine has been detected. It can be assumed that, providing contact is held sufficiently long, the ultimate destruction of a submarine is assured.[541]

The Fourth Escort Flotilla and a Fast Submarine

In the late spring of 1948 USS *Trumpetfish* visited Britain at the invitation of the Admiralty.[542] She was one of the early "Guppy" conversions which, by streamlining and "Greater Underwater Propulsive Power", was capable of submerged speeds of about 17 knots for an hour.[543] *Trumpetfish* was thus equivalent to the Type XXI and the Intermediate (B). In the waters off Londonderry, she carried out a series of exercises with the 4EF under its Senior Officer, Captain E.A. Gibbs, DSO***, who had sunk three U-boats (and a Vichy French submarine) during the war. The exercises with *Trumpetfish* began at the end of May and included attack, offensive sea-air hunting and

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540 'Progress in Underwater Warfare, 1947,' ADM 239/421, p. 34.
541 'Progress in Underwater Warfare, 1947,' ADM 239/421, p. 35.
542 'Semi-Annual Summary of US Naval Forces Eastern Atlantic and Mediterranean, 1 April 1948 – 1 September 1948,' Commander-in-Chief, US Naval Forces Eastern Atlantic and Mediterranean, to Secretary of the Navy, 14 October 1948, LHCMA, MF 868.
543 Friedman, *U.S. Submarines*, p. 242.

convoy serials. These exercises, and the longer series that was to follow with the Sixth Destroyer Flotilla, were to confirm that defensive operations to protect a force or a convoy, and offensive hunting missions had low probabilities of destroying enemy submarines. They therefore reinforced the accepted notion that a much wider cocktail of A/S measures were needed to effectively counter the modern submarine threat.

Gibbs' offensive sea-air hunting exercises began with a Coastal Command Lancaster gaining sonobuoy contact {*Plate 21*}. The sonobuoys used at this time operated on one of twelve different radio frequencies, split into two groups denoted by a white or black band. Within each group the six frequencies were indicated by the colours purple, orange, blue, red, yellow and green. The standard "POBRY" sonobuoy pattern derived its name from the colour (and hence frequency) sequence in which the sonobuoys were laid, i.e. purple on top of the datum, followed by orange, blue, red and yellow buoys normally on the cardinal points at 2,500 yards from the purple buoy. This method of deploying the pattern took about 5 minutes for naval aircraft and up to 10 minutes for shore-based aircraft. Attempts were made to speed up the deployment speed by laying the red buoy first in an estimated position en route to the datum, and the aircraft then flying a "Clover Leaf" pattern.[544] Speed was essential, for an Intermediate (B) at 15 knots could be on the edge of the pattern by the time the aircraft completed laying it. The aircraft would then have to lay an extension pattern in order to maintain contact until the surface A/S force could arrive. Extension patterns were made up of two or three additional buoys (depending on whether one buoy of the original pattern could be used in the extension) laid in equilateral triangles of 2,000 yard sides with the apex close to the submarine's estimated position.[545] This tactic was employed with limited success during the exercises with *Trumpetfish* with 4EF homed from 30 miles away. The tactic relied, however, on the submarine maintaining high speed so that her HE could be tracked on the sonobuoys. Submarines quickly learned that high speed was useful to clear the immediate datum, but thereafter moderate speed allowed them to put further distance between themselves and their hunters, while not making enough noise to be detected. Such tactics worked equally well against A/S vessels. The speed, Gibbs remarked, which most often baffled A/S vessels was about 8-9 knots, when the submarine would produce barely any HE signature, yet would be able to manoeuvre well clear of the ships' asdic sweep, given the relatively long range at which the submarine could detect the approaching escorts.

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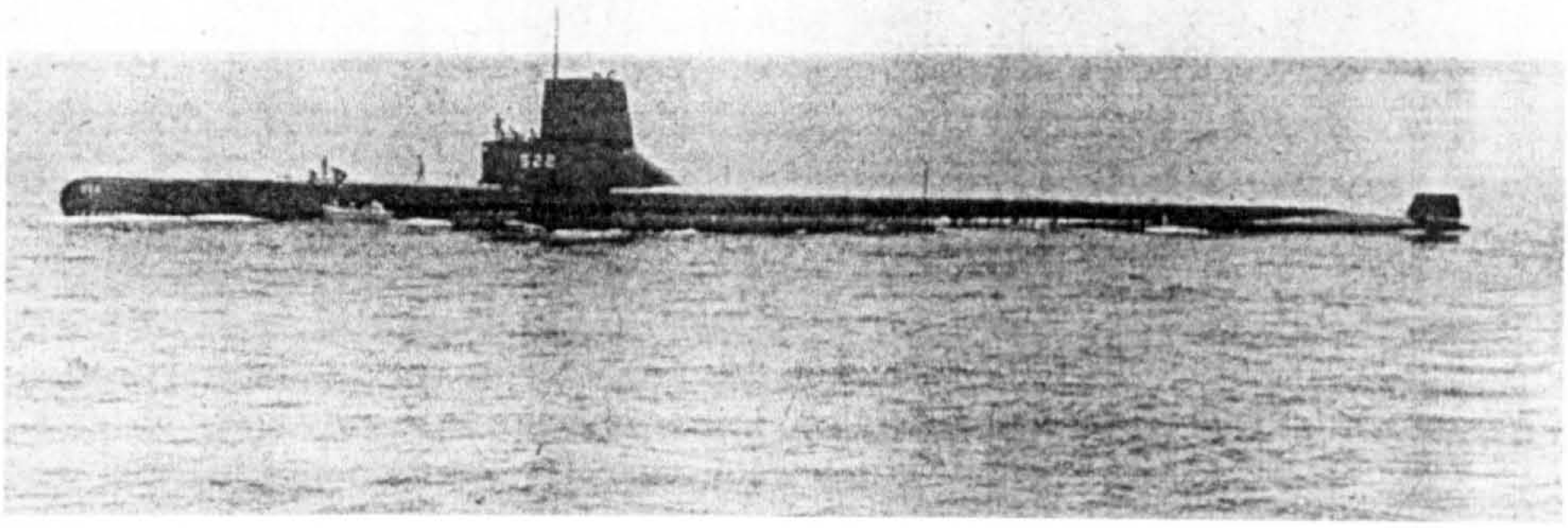
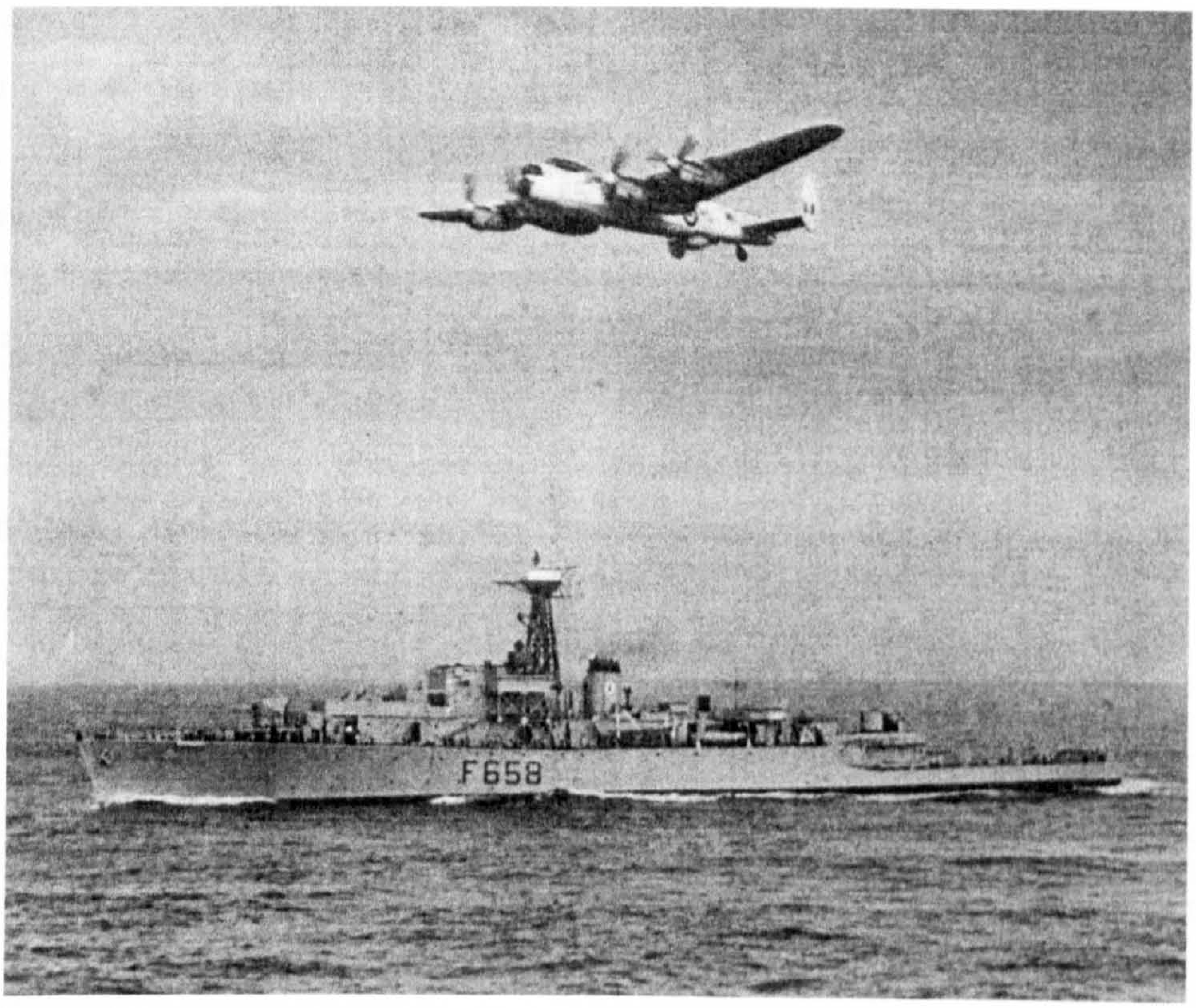
[544] 'Conduct of A/S Operations by Ships and Aircraft,' Admiralty and Air Ministry, CB04097(1/51) and SD 697(1/51), TASW.196/50, 3 October 1951, Box 468, RG 38, NARA2, Part 4, pp. 43-49.
[545] 'Aircraft and Aircraft Carriers,' Part 4 of 'Conduct of A/S Operations...,' Box 468, RG 38, NARA2, pp. 46-47.

Plate 21: Guppy, Fourth Escort Flotilla and Lancaster

'Progress in Underwater Warfare, 1948 Edition,' DTASW, T.A.S.W. 53/49, CB 04050 (48), 10 September 1949, ADM 239/422.



Guppy



Fourth Escort Flotilla Ship and Lancaster

It had been Gibbs intention to use the "Ring" tactic to contain and attack *Trumpetfish*. But even in the more stereotyped serials he found that the manoeuvring of the "Ring" in strict formation was something of a strain on personnel during a long hunt of a fast submarine. As a result the direct tactical co-ordination of the "Ring" was relaxed. The first ship to gain a firm detection of the submarine was designated as the "Contact Ship", and was given total freedom of manoeuvre as necessary to maintain contact. The rest of the flotilla would then

> ...conform by eye and plot to the contact ship's movements, except in rare conditions when the SO found it was necessary to initiate a drastic alteration of course or speed by signal. Attacking ships were detailed by the SO, the choice falling upon the most suitably placed ship. The hunt was in the main conducted from the Bridge, which has the great advantage of immediate realisation of one's consorts angle of inclination. The flow of information from the Plot to the Bridge was satisfactory and this coupled with the view of plots necessitated only infrequent visits to the AIC [or Action Information Centre]. The handling of the consorts presented no difficulty and this form of loose "Ring" has the great advantage of being not in the least tiring, and the hunt could, ...[Gibbs thought], be continued almost indefinitely without undue fatigue.[546]

During the more tactical serials 4EF quickly appreciated a more dramatic problem. With the submarine with a full battery and travelling at 14 knots or more, the frigates of the hunting force had insufficient speed to overhaul *Trumpetfish* and form a "Ring" around her unless she made a tactical mistake. So the serials degenerated into a stern chase, not dissimilar to those experienced during the *Seraph* trials four years earlier, with the frigates clinging onto the submarine's HE bearings. Unable to fix the position of *Trumpetfish*, Gibb's ships became scattered and vulnerable to counter-attack by the aggressive submarine not distracted while trying to attack a convoy. In one serial, assisted by very poor asdic conditions, *Trumpetfish* probably succeeded in '...sinking all the hunting vessels in turn.'[547] The A/S ships achieved little recompense and Gibbs found the experience '...disastrous and profoundly depressing.' Nevertheless, he was able to salvage a modification to the "Ring" tactic, which he termed Operation "Umbrella", as a general chase, in which:

> The ship in contact represents the handle of an opened "Umbrella", and the consorts spread evenly in loose formation around the perifory [sic] of the "umbrella" astern of the contact ship, the shaft of the "umbrella" pointing through the contact ship towards the submarine. Once formed there is no need to signal a new shaft and escorts conform to the movements of the contact ship. Wing escorts are well placed to intercept if the submarine breaks out to a flank; rear escorts are well place if the submarine doubles back under the contact ship and contact is lost; and

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546 'Exercises with USS *Trumpetfish*,' Captain E.A. Gibbs, 11 June 1948, Box 96, RG 313, NARA2, p. 5.
547 'Exercises with USS *Trumpetfish*,' Box 96, RG 313, NARA2, p. 4. [emphasis supplied]

> all rear escorts are well placed to form a line abreast search for echo contact if the submarine slows down and HE contact is lost.[548]

4EF did not have the monopoly on problems. *Trumpetfish*, too, found great difficulty in finding and approaching its target during the convoy serials. She had, realistically, been given long distances to make to close the convoy. If she was to arrive with a reasonable charge in the battery, she had to snort *en route*. She was also constrained by barriers of sonobuoys laid by Lancasters which forced her to slow down to avoid detection, which reduced her overall mobility sufficiently that she was often unable to close the convoy. This led the Admiralty to support the use of sonobuoys in this way. However, it was noted that when submarines lurked ahead of the convoy, the closure problem was greatly eased and they were sometimes able to penetrate the screen by going deep at high speed and by attacking the escorts. *Trumpetfish* also used high speed in an attempt to get under the convoy but was frustrated because she could not determine when she was in station due to the poor asdic conditions. Overall, the Admiralty concluded that although existing '...methods of defence of a convoy against a fast submarine appear sound, ...[they] constitute little effective defence against long range torpedo attack.'[549]

In reviewing the experiences of these exercises, often in difficult asdic conditions and against an aggressive, well-handled submarine, Gibbs remarked on the value of an early attack by the first escort gaining contact. Immediate attacks he thought would gain the initiative for the escort and possibly inflict some damage on the enemy, both of which would limit the submarine's powers of evasion and offence. Moreover, contacts were often fleeting, so every opportunity for attack had to be taken, for '...the escort Captain who does not take the chance which is given him neither deserves nor gets the chance again.' He also realized that, in war the norm would be for single- or pair-ship hunts of a fast submarine, and training of these tactics was just as important as exercising the "Ring" formation. In more favourable conditions Captain (D), Third Escort Flotilla,

> ...found that the ring of ships, and contact with the submarine, was maintained very easily and on one occasion it was possible to follow *Trumpetfish* with confidence until the submarine was forced to reduce speed for lack of amps.[550]

Such results, when compared to the pessimistic results from the 4EF's exercises, the Admiralty pointed out, 'emphasise the caution that must be exercised when assessing

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548 'Exercises with USS *Trumpetfish*,' Box 96, RG 313, NARA2, p. 8.
549 'Progress in Tactics, 1949,' DTSD, TSD.109/49, CB03016(49), 29 September 1949, ADM 239/565, p. 61.
550 'Progress in Underwater Warfare, 1948,' DTASW, TASW.53/49, CB04050(48), 10 September 1949, ADM 239/422, p. 40.

results from trials carried out under controlled conditions.'[551] These results showed that A/S warfare continued to be difficult, so simply waiting on the "defensive" for a submarine to approach a convoy would not guarantee its destruction. Nor was there a single "panacea" solution. Wider "offensive" remedies also had to be pursued for a future A/S campaign to be successful. These placed additional demands on force levels, so the requirement for these remedies had to be accorded a high priority amidst the many competing demands on naval resources.

[551] 'Progress in Underwater Warfare, 1948,' ADM 239/422, p. 40.

Chapter 7: Tactics, Technology and Trident, 1948-1949

Anti-Submarine Warfare Policy Debate

The experience of the Second World War highlighted that the primary striking power in modern navies were provided by aircraft carrier air groups. During the summer of 1948 Captain G. Barnard, the Director of the Royal Naval Tactical School, asked for guidance on the roles envisaged for naval aircraft in a war during the next five years. The Tactical School was endeavouring '...to swing thought away from massed "carrier slogging matches" of the Pacific War....'[552] He wanted to shift the bias to anti-submarine work by carrier support groups, which was to take up a third of the course. Time would also be spent on the defence of convoys in a high air threat environment, along the lines of Operation "Pedestal", as well as limited attacks at source.[553] Captain E.H. Shattock, Director of Air Warfare (DAW), broadly agreed with these proposed roles. However, Captain H.G. Dickinson, the Deputy D of P, suggested a modification to the list of roles which, he felt, would give a clearer picture of the intentions and limitations of naval aviation policy. The primary role of naval aviation, Dickinson suggested, was the protection of naval task forces and convoys in open waters. In this role the carriers would provide air support either as part of the task force or convoy, or acting independently as a patrol group. Their task was to provide protection from enemy submarines and to counter his reconnaissance aircraft. In enclosed waters, such as the Mediterranean, carriers, as part of a task force would provide protection primarily from shore-based air attack. Dickinson supposed that after the war had been in progress for eighteen months, the main strength of the carrier force would have been built up sufficiently to execute more offensive roles, including attack-at-source.[554]

Whether the Royal Navy should abdicate an offensive role, at least for the first eighteen months of a future war, was already being debated within the Naval Staff. In mid-July 1948 Captain R. Dick, the Director of the Tactical and Staff Duties Division (DTSD), agitated for Board approval over the apparent divergence between the policy

[552] Minute, Captain E. Shattock, DNAW, 14 July 1948, ADM 1/24518.
[553] 'Guidance on Future Tactical Problems for Naval Aircraft,' Captain G. Barnard, RN, The Director, RN Tactical School, TC No. 166/1/5, 18 June 1948, ADM 1/24518.
[554] Minute, Captain H.G. Dickinson, for D of P, 20 July 1948, ADM 1/24518.

which D of P was developing and the actual study and thought of the Naval Staff. 'At the risk of over-simplification,' Dick,

> ...would define this policy as yielding to the Americans all responsibility for offensive maritime operations while accepting for the British Navy the defensive role of convoy escort.[555]

Yet, Dick pointed out, inside the Admiralty and in the Fleet, tactical investigations were being based on the assumption that the Navy would be used offensively. This dichotomy, he thought, might be a suitable topic to be included in the forthcoming "Trident" conference. When Vice Admiral Sir Philip Vian, Fifth Sea Lord and Deputy Chief of Naval Staff (Air) weighed in he suggested that DTSD was raising wider issues. Echoing the castigation by several senior officers of what was seen as the "defensive" emphasis before the Second World War, Vian wondered if it was right to depart from traditional strategy and revert to a defensive policy, because the available forces were so small. These comments tended, probably unintentionally, to accentuate the idea that "offensive" and "defensive" measures were alternatives. In the sort of language that, as will be seen, worried the Historical Section Vian asked if '...a policy under which you are always waiting for the enemy to slog you, and never have him guessing about the safety of his own guts, succeed?' Surely, he thought, '...however slight our forces, should not some proportion be set aside for offensive action?' Vian was personally convinced that

> ...the very foundations of the Navy and all for which it stands will be undermined if we find ourselves at the outbreak of war, and for some years thereafter, having surrendered all striking power to other Services and other Navies.[556]

Somewhat less heatedly, he also pointed out that the draft setting for "Trident", for which he was the Directing Officer, did depict the Navy defending by attacking. When the new First Sea Lord, Admiral of the Fleet Lord Fraser of North Cape, replied to Vian he firmly pointed out that: 'Planning can only proceed on something we know we must do; escort safely our convoys.'[557] Curiously, Fraser was not convinced that it was possible, at this stage, to identify suitable Russian targets for offensive action, though there seemed to be a role for the air forces in striking at submarine bases. Typically, this did not satisfy Vian. 'Before this dog is laid...' he took another swing at the issue. He thought there was a definite role for offensive operations against enemy

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[555] 'Policy and Fleet Tactical Training,' R. Dick, DTSD, TSD.4580/48, 14 July 1948, ADM 205/69.
[556] 'Maritime Policy as it affects Exercise "Trident",' P.L. Vian, Fifth Sea Lord, 10 September 1948, ADM 205/69.
[557] 'Maritime Policy as it affects Exercise "Trident",' Fraser, First Sea Lord, 14 September 1948, ADM 205/69.

airfields on the flanks of convoy routes and for attacks against submarine bases. Doubtless, thinking of the difficulties experienced in establishing an offensive role for the British Pacific Fleet during the war, he asked if it was possible for more emphasis could be put into these operations, even if other Allies then had to shoulder more of the "defensive" burden? Perhaps, too, the British experience in the Mediterranean and, especially, the Arctic would pay dividends, for it was in these theatres that strikes would be most likely.[558]

When Captain T.M. Brownrigg, D of P, entered the debate he made it clear that his Division were not believers in defensive warfare, and that they did not agree to all offensive operations being undertaken by the Americans.[559] Instead his approach was one of pragmatism. Possible offensive operation were considered against their value in furthering immediate objectives and ultimate British war aims, and taking into account whether the British possessed sufficient forces to carry out such operations successfully, without prejudicing more important missions. As a result, Brownrigg had obtained Board approval for offensive minelaying and an offensive submarine A/S policy. Other plans were also being submitted for offensive operations in the Black Sea and off the Norwegian Coast if the enemy were to launch a sea borne assault on Norway. Thus the difference in opinion was reduced to the air strike policy. The existing force of aircraft was barely 170 first line aircraft, which was planned to be expanded to 300 by 1957. Brownrigg, like Dickinson before him, suggested that the main roles to be undertaken with this small force ought to be fighter defence of fleets and convoys, A/S operations, and, where possible, strikes should be made on enemy shipping and shore installations. He was somewhat optimistic, for the previous First Sea Lord, Admiral J. Cunningham, had stated that fighter protection and A/S operations were the top priority, so there would be negligible forces left for the strike role. By contrast, the USN had concentrated on naval aviation and could deploy about 1,100 carrier borne first-line aircraft as opposed to the Royal Navy's 168. Moreover, the Americans thought that a strike by less than 200 aircraft would be ineffective – an idea with which Brownrigg agreed. He pointed out that if the existing small strike force was used it was likely to be decimated, as had happened in Norway in 1940. He considered that the policy for the Royal Navy, should war come, was to employ the fighter and A/S aircraft available (which would fulfil the minimum requirements), and to use the small strike force as a nucleus upon which to build a more effective striking force of about 200 aircraft. Ultimately, the front line strength would be expanded to some 600 aircraft by about 20

558 'Maritime Policy,' P.L. Vian, Fifth Sea Lord, 15 September 1948, ADM 205/69.
559 'Maritime Operations,' T.M. Brownrigg, D of P, 28 September 1948, ADM 205/69.

months into a future war, distributed in 15 squadrons each of A/S, strike and day fighter aircraft, and 5 squadrons of night fighters.[560] Fraser, agreed to this policy and authorised Brownrigg to discuss it with the Americans in the forthcoming staff talks.[561]

A Second Tranche of Doctrine Papers

In parallel with this wider debate, by the summer and autumn of 1948 Captain C.E.E. Paterson in DTASW had produced a more detailed set of doctrine papers, which refined their more philosophical predecessors of 1946-47 discussed in Chapter 5. Gone was the historical background. Instead the new papers read more like doctrine manuals, which, with further expansion over the next three years, is what they became. Emphasis was still placed on convoy and fleet protection by surface and air escorts and two of the major papers dealt with these aspects.[562] However, the more offensive doctrine concepts are now displayed in separately in a paper on the tactical employment of patrol groups, operating either independently or in direct support of convoys.[563] Copies of these documents were issued widely within British forces, and also sent to Canada and America where they were studied by a Joint RN, USN and RCN Committee meeting in Washington with the object of standardizing A/S tactical doctrine.[564] The papers were originally intended to be applicable to the "short-term" problem against the submarine threat up to 1950. This timescale was later extended to mid 1951 by the Sea/Air Warfare Committee.[565]

The doctrine papers were based on the foundation work done by Burnett and his team in 1946-47, sea exercises and tactical table games at JASS, Fleet exercises and, of course, wartime experience. They also contain many echoes of the doctrine developed during the interwar period, especially in the overall function of escorts, and supporting forces. After a delay of some months, Paterson began by commenting at some length on the earlier convoy defence analysis done by JASS. Most of his comments concerned JASS's implicit assumptions of the technological capability of A/S

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560 'The Proposed Policy for Build-up of Naval Aviation after the Outbreak of War,' Appendix II to 'Maritime Operations,' T.M. Brownrigg, D of P, 28 September 1948, ADM 205/69.
561 'Maritime Policy,' Fraser, First Sea Lord, 29 September 1948, ADM 205/69.
562 'Defence of Ocean Convoys against Submarine Attack,' DTASW, TASW.397/48, August 1948, AIR 20/6384; 'Defence of Fleet Units against Submarine Attack,' DTASW, TASW.380/48, August 1948, AIR 2/5950.
563 'The Tactical Employment of Patrol Groups,' Sub-SAWC/II/63/48, [TASW.404/48], [30 September 1948], AIR 2/5950.
564 'Anti-Submarine Tactical Papers,' Naval Secretary, Naval Service, Department of National Defence, NSS 8100-5 (Staff), 3 February 1949, File 8100.5, Vol. 3734, RG 24, NAC.
565 'Joint Sea/Air Warfare Committee: Report by the Joint Secretaries of the Joint Sea/Air Warfare Sub-Committees on the work carried out since 28 June 1949,' SAWC/I/50/2, 21 July 1950, AIR 20/6842.

forces to counter the Intermediate (B) submarine: including radar interception gear and improved asdic. He was more sanguine, than JASS, over the chances of these capabilities being available in the near term. On one tactical point, he agreed that once a submarine had manoeuvred under a convoy it would be very difficult to counter. JASS had suggested the use of a plan called "Parsnip" which involved the convoy making an emergency 90° turn, with the idea of uncovering the submarine long enough for the escorts to locate and destroy it.[566] Paterson, however, considered the plan of '...limited use.'[567] Otherwise, Paterson had little of substance to add and the JASS work formed the basis for DTASW's own examination of convoy and fleet defence, as well as offensive operations. Furthermore, JASS's assessment of the problems confronting enemy submarines was reproduced practically verbatim by Paterson.[568]

It was expected that the enemy would try to avoid compromising the position and composition of his submarine patrols. Nevertheless, it was hoped that shore station D/F of enemy submarine W/T transmissions, as well as sightings by aircraft and surface craft, would provide sufficient intelligence of submarine operating areas, to allow at least a measure of evasive routeing of both convoys and Fleet units. The Fleet, of course, would retain one major advantage over convoys, that of high passage speed which would be greater than the submerged speed available to modern submarines. This, combined with a random zig zag, would give the Fleet a considerable defensive advantage, though it would consume fuel at a high rate, especially amongst the screening A/S destroyers. As in the past, the Fleet and its supporting replenishment units, would be screened by a force sufficient to provide a reasonably "watertight" A/S barrier, capable of detecting any approaching submarine and counter-attacking it. There would never be enough escorts to provide such luxury for convoys. But, provided there was an adequate level of intelligence to identify threatened convoys, the intention was to give each convoy a weak "through" escort, which would be reinforced in danger areas by a surface "Patrol Group" (which may include an aircraft carrier). It was even hoped that, using the intelligence, some ships could still sail independently through areas where the danger was slight, which would speed up the delivery rate, as well as saving on escort requirements. It can be seen that these ideas reflected much of the experience of the late war. However, whether adequate intelligence would be available was a moot point. Little hard evidence has emerged that the British, or the Americans,

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566 'Progress in Tactics: 1947,' ADM 239/143, pp. 15-16; 'Trade Protection – Defence of Ocean Convoys,' Box 102, RG 313, NARA2, Appendix VI.
567 Reference Sheet, 'Defence of Fleet Units against Submarine Attack,' C.E.E. Paterson for DTASW, TASW.380/48, 19 August 1948, AIR 2/5950.
568 'The Problem Confronting Enemy Submarines,' TASW.396/48, August 1948, AIR 20/6384.

had broken into Russian codes from which special intelligence would be forthcoming to assist in a future A/S campaign. Perhaps, more was achieved, at least by the Americans, at the end of the decade.[569]

Since the submarines' method of attack was thought to be essentially the same as during the war, escort dispositions were fundamentally the same. However, the use of submerged tactics meant that there might be little warning of an attack, so the surface escort needed to be disposed in such a fashion that it could exploit initial asdic contacts quickly. The higher submerged speed of modern submarines meant that in order to do this A/S vessels would need to be further out to give them more fighting room, and also disposed in depth, so that the detecting ship and a "pouncer" could concentrate to counter-attack an approaching submarine. The escorts would also have to cover the sector between the wider Limiting Lines of Submerged Approach available to the Intermediate (B). Against a convoy, it was even possible for these submarines to close submerged from a short distance astern, as had been deduced during the war. Even so, it was thought that submarines would still prefer to fire from a position broad on the bow of a convoy or Fleet unit. It was concluded, from tactical table modelling at JASS, that the minimum escort strength for a 60-ship convoy was eight escorts (about 125% of the recent wartime provision), rising to 12 in focal or submarine patrol areas.

For the Fleet containing carriers protection would have to be extended to an all-round "circular" screen to allow for the carrier's manoeuvring during flying operations. In the past, it was best to avoid adjacent ships having the same asdic frequencies (so as to avoid mutual interference), and it was also ideal to widely separate HF/DF fitted ships (to provide a long baseline for triangulation). Now, consideration had to be given to sensible stationing of ships which would soon start to be fitted with VHF, UHF, and centimetric radar D/F equipment. If contact was gained by D/F, or a sighting, the papers advised that initially an aircraft should be sent to investigate, unless the contact was close and presented an immediate threat. This was especially relevant to the case of Fleet defence, where detachments of surface escorts would dilute the screen for a considerable time while they regained station after the hunt. Even in the case of the slower convoy, it was inadvisable to send a surface force if the contact was more than 10 miles distant because of '...the great distance that a submarine may cover submerged before surface escorts arrive....'[570] The best policy was felt to be that the

[569] Peter Hennessy, *The Secret State: Whitehall and the Cold War* (London: Allen Lane, 2002), pp. 19-20; 'USSR General Report,' CX Report, 10 October 1945, WO 208/4566; 'Top Secret Annex to Study of Undersea Warfare,' 22 April 1950, Command File, Post 1 Jan 46, CNO Studies 1950, Box 475, OA, NHC.
[570] 'Defence of Ocean Convoys...,' AIR 20/6384, p. 4.

aircraft should lay a sonobuoys pattern around the datum position and if contact was gained then surface escorts could be sent. In any case, a minimum of two escorts were to be sent for mutual support.

As for air support in general, convoys were to be given a light escort from shore-based or carrier-borne aircraft in a danger area. It was envisaged that the balance of shore-based aircraft would be flown on independent patrols over submarine danger areas, from whence they could be diverted to reinforce threatened convoys. These tactics were preferred to providing "through" air escort because they would ensure that the danger areas were covered comparatively frequently, and this would hinder the movement of submarines. Moreover, although the chance of detecting a snort was low, it was better to support convoys that were threatened, for submarines would be attempting to concentrate against them. Even if the submarines did not risk using surface travel, they would probably have to snort, and this would give aircraft a greater chance of gaining a detection. These tactics would, however, rely on a reasonable level of intelligence to define the danger areas, and those convoys which were threatened. Especially, if there were indications that a convoy had been reported, it could be assumed that other submarines would begin to concentrate ahead for an attack. The priority was for air escorts to locate and, if possible, destroy the contact-keeper and then to prevent the other submarines from achieving their concentration. These tasks would be made easy if the submarines were discovered on the surface, but this was unlikely unless the enemy was a considerable distance from the convoy and unable to intercept without surfacing. But even submerged, the enemy would have to move a relatively high speed, probably snorting for a considerable proportion of the approach. These submarines could be detected by sonobuoy barriers laid either at right angles to the convoy's track to catch the shadower, or parallel to the track to detect submarines approaching from the beam or broad on the bow. These prophetic tactics were still awaiting the development of the technical means, especially of an effective airborne weapon capable of being used in an attack on a submerged submarine.

For the protection of the Fleet, on the other hand, A/S air escort was to be continuously provided. Not only would these aircraft have a chance of detecting submarines, but would also force others to submerge, which might have reported the Fleet. This, in turn, would help to secure knowledge of the planned operation being undertaken by the Fleet. The priority for air search was to cover the outer area ahead and on the beam, about 20 miles from the Fleet, just on the limit of a submarine's hydrophone detection range on the Main Body. Here submarines might be on the surface, trying to get into position ahead of the Fleet where they could get contact on their own sensors. Once this patrol was covered, aircraft were to maintain a continuous patrol some 3 to 5 miles on the beam and ahead of the Fleet where they could harass submarines using their periscope or radar to gain a final fire control solution. Any additional aircraft (most likely to be shore-based) could be used for independent patrols and searches at a distance from the Fleet.[571]

The enemy was also expected to make heavy use of reconnaissance aircraft to locate and shadow Fleet units and convoys. Admiral of the Fleet of the Soviet Union S.G. Gorshkov wrote in the 1970s that the Germans made '...no small error...[by] waging the struggle virtually only with submarines, without backing them up with other kinds of forces, especially aircraft.'[572] Mahan would have understood the point, and it was equally obvious to the British immediately after the war.[573] This aspect was not, however, as simple as it seemed. The Joint Intelligence Sub-Committee noted in late 1946, that while the Germans had had many opportunities to modify their strategy early on in the war, the increasing power of the Allies soon circumscribed their flexibility. In their assessment, the Sub-Committee also noted that Dönitz displayed little aptitude for strategic thinking and that the Germans suffered throughout from the poor co-operation between the *Luftwaffe* and the U-boats in the Atlantic. They also pointed out that the system had worked somewhat better in the Arctic.[574] The limited reconnaissance capability of submerged submarines, meant that they would have to rely more heavily on reports from shadowing aircraft. These enemy reconnaissance aircraft were, therefore, prime targets for friendly fighters.

Despite these precautions, attacks were still likely to develop. The most difficult decision a Senior Officer would have to make was whether the attack was made from outside or inside the screen, or, in the case of a convoy, from beneath the convoy itself. Both the defence of convoy and of the Fleet papers emphasized, in the event of a surprise attack, the need for pre-arranged search schemes, capable of being put into instant operation to cover these contingencies by surface escorts. There was little that air escorts could do to help A/S vessels if the submarines were at close quarter with the convoy or Fleet. However, aircraft should be used to search the area astern where the attack took place, hopefully detecting submarines whose positions are roughly

[571] 'Defence of Ocean Convoys...,' AIR 20/6384, pp. 1-6; 'Defence of Fleet Units...,' AIR 2/5950, pp. 1-6.
[572] S.G. Gorshkov, *The Sea Power of the State* (Annapolis, Maryland: Naval Institute Press, 1976, translated 1979), p. 118.
[573] Mahan, *Influence* (c.1889), p. 196; A.T. Mahan, *The Influence of Sea Power upon the French Revolution and Empire, 1793-1812*, Vol. I (Boston: Little, Brown & Co., 1895), pp. 179-180.
[574] 'German U-boat Strategy in the War,' Appendix XVIII, to 'Some Weaknesses in German Strategy and Organisation, 1933-1945,' Report by the Joint Intelligence Sub-Committee, JIC(46)33(Final), 20 October 1946, NHB, pp. 180 and 183.

known, and needing to re-charge their batteries, attempting to shadow or assess the results of their attack. If surface escorts were also available, it was possible that defending forces might inflict casualties during this phase.[575]

By September 1948 Paterson had drafted the paper on "The Tactical Employment of Patrol Groups" which, after comment by the Naval Staff, was put before the Sea/Air Warfare Committee in mid October. There, after minor amendments, the paper was approved for issue to Naval and Air Commanders-in-Chief, and authorities responsible for training and research in A/S problems. A Patrol Group, DTASW thought, should consist of a minimum of a carrier capable of day and night operations and at least four A/S vessels able to provide both a screen for the carrier and an offensive striking force. It was realized that early on in a war, it was unlikely that sufficient numbers of carriers and escorts would be available to meet all Patrol Group requirements. Shore-based aircraft of Coastal Command could partly fill the gap, though the situation would not be rectified until more ships became available. Patrol Groups could be used '...offensively as "Hunter-Killer" groups...or as a reinforcement to close escort of convoys passing through submarine probability areas.'[576] Their purpose was to destroy submarines. To achieve this a Group was to operate on enemy's transit routes and in his operational areas, using its aircraft as the means of searching over large areas. A proportion of the A/S escort was to be released to form a striking force to hunt submarines to destruction when detected by air searches or pinpointed by intelligence.

These offensive operations were divided into two phases: first the gathering of intelligence, and then the hunting and destruction of the submarine. Intelligence would be gathered from aircraft sightings, reports of attacks on shipping, and from interception of electromagnetic transmissions from submarines. This effort would be supported by the use of shore-based aircraft flying "box" patrols within suspected submarine areas or over transit routes. The co-ordination between the Patrol Group and Coastal Command aircraft would be through the Area Combined Headquarters (ACHQ), and, for specific hunts, shore-based aircraft could be put under the direct command of the Patrol Group Senior Officer. His own carrier-borne aircraft were to be flown on searches, which reflected the practice at the end of the war. The depth of these searches should be no more than 40-60 miles, and was regulated by two factors. This was the distance which surface escorts could steam in about 2½ hours, which was

[575] 'Defence of Ocean Convoys...,' AIR 20/6384, pp. 5-7; 'Defence of Fleet Units...,' AIR 2/5950, pp. 5-6.
[576] 'Tactical Employment of Patrol Groups,' AIR 2/5950, p. 1.

about as long as an aircraft was likely to hold contact with sonobuoys on a submerged submarine. If the escorts arrived later than this, and the aircraft was out of contact, they would have little chance of regaining the scent. The "hunt to exhaustion" practiced during the war, was unlikely to be watertight against a modern snort-fitted or Intermediate (B) submarines. If the aircraft lost contact, it was recommended that a containing circle of sonobuoys be dropped, unless a rough direction of escape was known, when a sonobuoy barrier could be laid across and ahead of the suspected track of the submarine. A maximum air effort was to be mounted to fly patrols spaced around the datum, hoping to pick up the submarine snorting, or to follow up surface ship HE detections with sonobuoys.

Co-operating ships from the Patrol Group were to home to the aircraft contact at high speed and once at the submarine's furthest-on-circle (FoC) to reduce to search speed and carry out a wide zigzag, mindful of the danger of an attack with an anti-escort homing torpedo. The Patrol Group would concentrate its search on the most probable escape course in the light of available intelligence. This problem had been noted during the war when dealing with the snort-fitted U-boats in coastal waters, and was exacerbated by the improved performance of the Intermediate (B). The paper also examined the problem of a Patrol Group which was operating without a carrier and with no shore-based air support. Mathematical modelling (presumably by DNOR) suggested that the A/S ships should zigzag in a widely spaced formation to cover as much of the suspected area as possible. Consideration was also given to Patrol Groups working in Inshore Waters. It seems to have been assumed that in this case, there would be no carrier present. The advice given for asdic searching was the same as that provided during the war. If all these difficulties were overcome, and the escorts were able to gain contact, a co-ordinated A/S action was required '...by up to five ships...to provide the best chance of a kill.'[577]

Supporting these papers was work done at JASS at sea and on the tactical tables, as well as liaison visits to the USN. Considerable effort was being expended in the US on the Hunter-Killer concept, though they recognised that at least two escort carriers, with their attendant escorts, were needed to have any chance of holding down a single Type XXI U-boat. When Captain Richard Onslow, the RN Director at JASS, spoke to the Naval Air Conference in May 1948 he made it clear that convoy remained the central pillar of British shipping defence philosophy. But he also reiterated all the problems of surface and air escorts in locating and destroying submarines, as well as

[577] 'Tactical Employment of Patrol Groups,' AIR 2/5950, p. 3.

the enemy's greater power of attack especially if supported by reconnaissance aircraft. Onslow reminded his audience of the success of the Biscay and Northern Transit route offensives and suggested that similar results could again be achieved. However, as he pointed out, an aircrafts' ability to search large areas was severely limited by existing sensor technology. Worse, aircraft had no weapon capable of destroying fully submerged submarines, even if detected. Aircraft, would therefore have to work in conjunction with surface forces who would do the killing. Onslow emphasized that the success of the Patrol Groups rested heavily on intelligence of enemy submarine operations, and even then, on relatively small search areas.[578] The Americans had come to similar conclusions.[579] One of their reports subsequently noted that

> Because of the small chance of hunting down and killing a Type XXI or equivalent submarine with present Hunter-Killer groups, emphasis should be placed on convoy escort coverage by Hunter-Killer groups.[580]

Such ideas ran contrary to cherished USN views. Back in 1946 Vice Admiral Sherman, the Deputy Chief of Naval Operations, observed that '...the strategic counter to this sort of thing is high emphasis on attack at the sources of the trouble.'[581] These views – undoubtedly instilled by American experience during the Pacific War – were still strongly held in 1948. But they also highlight the enduring tension between, on the one hand, "offensive" search operations, that are always sensitive to technological superiority and (especially) intelligence cueing, and, on the other hand, "defensive" convoy operations which are more robust to technical deficiencies.

A Year of Exercises with Fast Submarines

While the 4EF was exercising with *Trumpetfish*, a more extensive set of trials and exercises were beginning with ships of Captain Sir Charles E. Madden's Sixth Destroyer Flotilla (6DF) {*Plate 22*}. Two of Madden's ships, *Battleaxe* and *Crossbow*, began by operating against a slow submarine and in the shore attack-teachers at Portland. Even so, they were comparative novices when they started a four-week work-

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578 'Item 6 – The Anti-Submarine Problem,' Captain R.G. Onslow, DSO, RN, Naval Director of the Joint Anti-Submarine School, in 'Minutes of Naval Air Tactical Conference held at RNB, Lee-on-Solent, 31 May to 3 June 1948,' AWD.394/48, n.d., NAA(M): MP1049/5, 1874/2/63.
579 'Fifth Partial Report (Part I) on Project Op/V32/A16-3(17)(Revised): Development of Air and Coordinated Surface Tactics for use Against the Medium Speed Deep-Diving Submarines (Hunter-Killer Groups),' R.P. Biscoe, Commander Operational Development Force, 30 June 1948, Box 96, RG 313, NARA2.
580 'Composition of Hunter-Killer Groups,' W.R. Edsall, Assistant Chief of Staff to Commander in Chief US Atlantic Fleet, FF13/A4-3(00189), 14 December 1949, Box 103, RG 313, NARA2.
581 'Proceedings of Anti-Submarine Warfare Conference, 17 June 1946,' Op-34H:jn (SC) A16-3(17) Serial: 00012P34, Forrest Sherman, Deputy Chief of Naval Operations, 25 June 1946, Microfiche F3642-1, Sheet 001, OA, NHC, pp. 28-29.

up with the 11-knot *Selene* in April 1948.[582] These practices were intended to prepare them for exercises with another Guppy, USS *Amberjack* off Key West in the Straits of Florida in July and August. These were to be followed by serials with HMS *Scotsman* and a third Guppy, USS *Dogfish* in the waters off Northern Ireland between November 1948 and March 1949. During these later exercises Madden would be joined by two more ships of his flotilla, *Scorpion* and *Broadsword*.[583] The whole series was designed to investigate the capability of existing A/S equipment to "kill" a submarine which is capable of proceeding at up to 18 knots submerged.

At least without the pressure of wartime operations, the trials were extensive enough to reach some statistical validity, though meaningfulness of the results was mitigated by the effect of peacetime safety restrictions on tactical realism.[584] The initial work-up soon confirmed the effect of submarine speed on the A/S ships' ability to kill a submarine. It took, on average, 45 minutes and 2 or 3 attacks for the ships to "kill" the "T" Class boat, but took about 1½ times longer and 1 or 2 additional attacks to "kill" *Selene*. *Selene* also escaped from the hunting ships on one-third more occasions, than the slower "T" Class.[585] The exercises which followed against *Amberjack* were very different in character. The American submarine was much larger and therefore gave a better asdic echo, but the water conditions were difficult and, unless *Amberjack* operated at shallow depth, asdic ranges were short. Capable of 19 knots, she was considerably faster than anything the British had operated against to date. Overall attack results were worse than against *Selene*. About 1 in 8 attacks resulted in a "kill", though if "surfacing damage" were included the success improved to about 1 in 5 attacks. The low success rate might seem to be pessimistic. However, the evasion manoeuvres carried out by *Amberjack* were usually calculated to give the attacking

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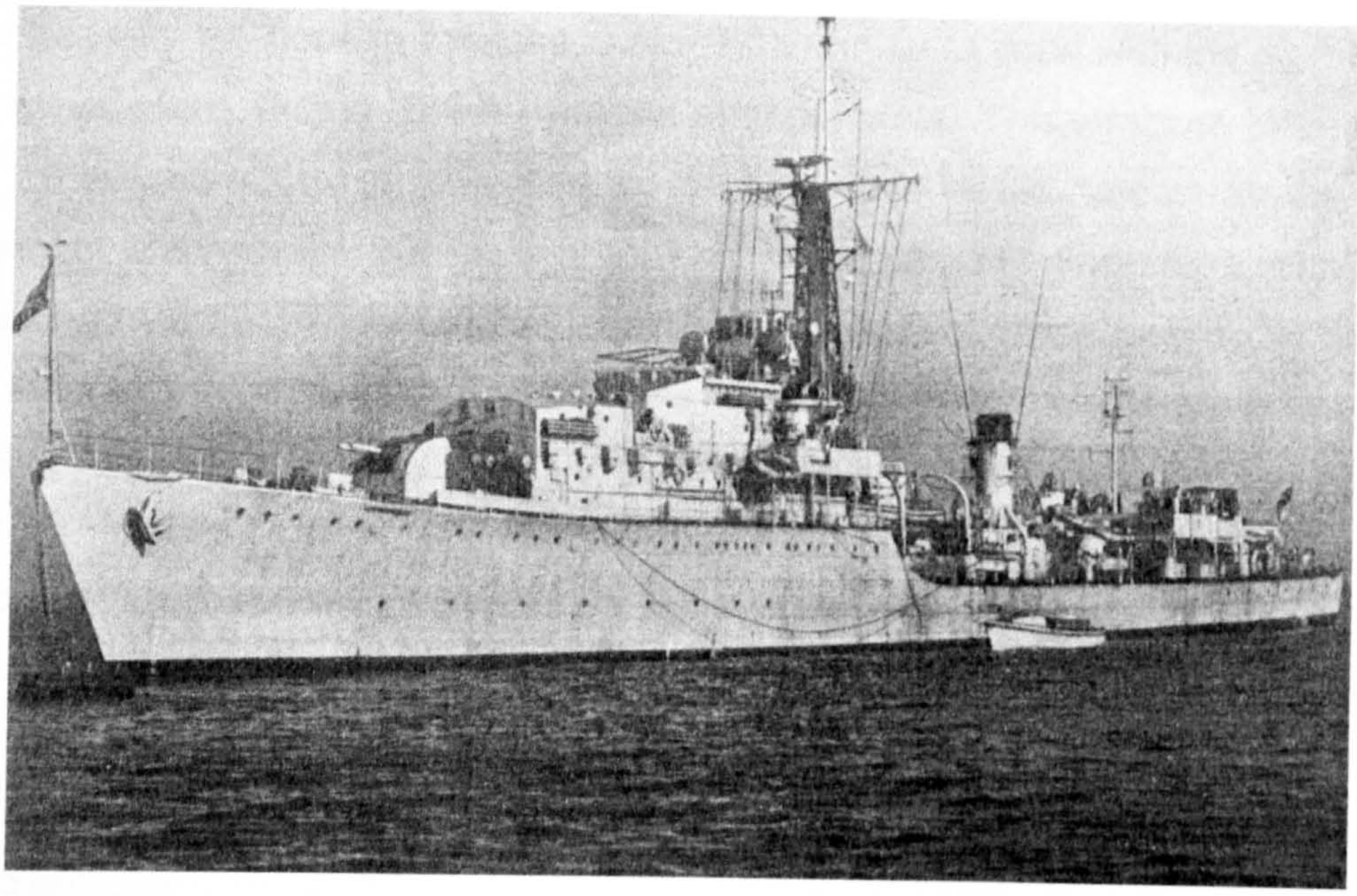
582 'Annual Report of TAS Schools, 1948,' UWD, CB4486(48), UW.05088/1949, January 1949, ADM 189/68, p. 23.
583 'The First Experience of A/S Actions with Intermediate (B) Submarines,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274, pp. 53 and 64.
584 Llewellyn-Jones, 'The Pursuit of Realism,' p. 234.
585 'The First Experiences of A/S Actions with Intermediate (B) Submarines: Addendum to CB04050(48) – Progress in Underwater Warfare, 1948,' DTASW, TASW.312/49, CB04050(48)(N), 1 December 1949, ADM 239/423, p. 6.

Plate 22: HMS *Broadsword* – Sixth Destroyer Flotilla

(IWM)



ship a more difficult attack solution than would be expected, on average, in a wartime engagement. 'In unrestricted A/S actions,' the Admiralty subsequently pointed out, 'it is more a matter of chance if the target takes avoiding action at the worst moment for the attacking ship.'[586]

Much of the difficulty in attacks was due to limitations in the asdic instruments, and particularly the bearing recorder, which was unable to cope with the high bearing rates experiences during these dynamic engagements. This problem was already being addressed with a modification to the Type 144 Asdic, known as the "Ships Component Mechanism", designed '...to remove the effect of own ship's motion from the bearing recorder trace during an attack.' Although trials with a "lash-up" of this gear were satisfactorily completed in 1947, the bearing recorder would have had to be redesigned if the gear was to be brought into service. Reflecting the policy stated earlier by Ashbourne, the scheme was to remain a "sealed design" that could be produced at short notice should it be proved that the existing asdic was not capable of competing with the 15 knot submarine. It was not, therefore, available to Madden's ships, and was eventually introduced when the modified Type 164 Asdic entered service in 1950.[587] Madden also rediscovered that the formal "Ring" tactic could not be put into practice

> ...because each A/S action very soon became a stern chase with the submarine doing 18 knots having had a few minutes start, and the two surface ships pursuing at 21 knots.[588]

The exercises with *Amberjack* also highlighted the importance of getting in an early attack before the scene of action became "waked-up" by the ships and submarine, and the vital role of teamwork. Thus when Madden's ships were joined by two USN destroyers the results were poor, with *Amberjack* tracked only intermittently, many reported non-subs and few attacks made. This seemed largely due to the differences of equipment between the four ships, and to the short time available for working-up as a team. Nevertheless, the two British ships had gained valuable experience which could be applied to their next set of exercises in British waters, this time against the British submarine, *Scotsman*, a more extensively modified "S" Class capable of 16½ knots. She had been a long time coming, which probably had more to do with the need for extensive trials needed to understand the complex nature of her underwater handling characteristics at high speed, rather than the result of financial

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586 'Progress in Underwater Warfare, 1948,' ADM 239/422, p. 37.
587 'Progress in Underwater Warfare, 1947,' ADM 239/421, p. 114; Hackmann, *Seek & Strike*, p. 338; 'First Commonwealth TAS Liaison Meeting...,' NAA(M): MP1185/8, 1846/4/343.
588 'Progress in Underwater Warfare, 1948,' ADM 239/422, p. 39.

restrictions.[589] She had not even been able to complete her "First of Class" trials before being needed for the exercises with 6DF.[590] *Scotsman* proved to be a difficult target – worse than the earlier conversions, such as *Seraph*.[591] Asdic conditions in the North Channel were poor and *Scotsman*'s echo was normally weaker than the reverberations. Often it could only be distinguished from its doppler by operators with good pitch discrimination. Close actions against *Scotsman* once more developed into stern chases and attacks were beset by the difficulty of distinguishing the echo from her wake. Attacks, overwhelmingly from abeam or astern, were uniformly unsuccessful when she was travelling at speeds in excess of 12 knots.[592]

During the two-ship actions greater tactical realism was allowed, for when contact was lost *Battleaxe* and *Crossbow* were allowed to use search schemes to re-locate the submarine, rather than the serial being stopped and then re-started once the submarine's position was confirmed as had been the practice previously. This was continued when *Scorpion* and, later, *Broadsword* also joined Madden's team. Thus on losing contact a search scheme was carried out until contact was either regained, or the exercise was terminated.[593] The previous experience of *Battleaxe* and *Crossbow* showed because they were able to keep in continuous contact with *Scotsman*, on average, for just over an hour. *Scotsman*, like the earlier S-class conversions, was not able to charge her battery at sea and so could only maintain 15-17 knots for short exercises of, say, 45 minutes. At 12 knots, however, she could manoeuvre continuously for up to 4 hours.[594] When contact was lost, it was regained by echo and HE on an equal number of occasions. This is hardly surprising, as when attacked *Scotsman* was likely to be travelling at high speed. Any immediate search would therefore have the chance of detecting her high echo doppler or HE, depending on the relative noise levels. But if an organized search was initiated after contact had been lost for longer periods, then when contact was regained it was always by echo,

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589 'Super *Seraph* – Submerged Control Preliminary Report. Report No. 25/46,' Superintendent, Admiralty Experiment Works, Haslar, to DNC, 11 November 1946, RNSM A1991/098; 'HMS *Scotsman*: Conversion to Fast A/S Target,' Section 27, DNC Department, October 1948, RNSM A1991/098.

590 'HM Submarine *Scotsman* – First of Class Trials,' G. Bryant, DNC Department to Flag Officer (Submarines), [5] November [1948], RNSM A1991/104; '*Scotsman* Trials,' G. Bryant to DNC, Memo dated 5 November 1948, RNSM A1991/104.

591 'Echo and HE Characteristics of the Submarine *Scotsman*,' J.W. McCloy, HM Underwater Detection Establishment Report No. 95, October 1951, ADM 259/29, p. 10.

592 'The First Experience of A/S Actions with Intermediate (B) Submarines,' ADM 239/274, p. 54.

593 'A/S Practices of HMS *Battleaxe*, *Crossbow*, *Scorpion* and *Broadsword* with HM Submarine *Scotsman* in the North Channel in January and February, 1949,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274, p. 71.

594 'HM Submarine *Scotsman*. Report of First of Class Trials,' Flag Officer S/M, Fort Blockhouse, n.d., RNSM A1991/104.

probably because *Scotsman* had slowed to avoid long-range detection of her HE. By now *Battleaxe* and *Crossbow* had a year of almost continuous A/S practice against fast submarines. Although much less experienced, *Scorpion* and *Broadsword* had absorbed much of the techniques of the senior ships during their A/S exercises in early 1949. Now the four ships embarked on the final set of exercises in this series, this time against the Guppy USS *Dogfish* in the North Channel during February and March 1949. *Dogfish* was much larger than *Scotsman* and proved to be a better asdic target, but she was quieter and 2 knots slower than the British boat.

Of the large number of attacks conducted against *Dogfish*, 15½% were against the submarine at speeds up to 6 knots, 84% at speeds between 7-12 knots, and only ½% at speeds over 12 knots. This was, by now, a relatively well recognised pattern. But some old precepts were also re-established, the main one being that two-ship actions were the most economical. Roughly the same number of A/S actions with 2, 3 and 4 ships were carried out. Although during two-ship actions, the interval between attacks was longer they were individually 1½ times as effective as for actions with 3 or 4 ships in producing a "kill" or "surfacing damage". On the other hand, two-ship actions were more likely to involve attacks on non-subs or to loose the contact altogether.[595] This finding, however, takes no account of the spare ships being used on a containing search around the close A/S action, where they might regain contact on the evading submarine. Nevertheless, as the Admiralty noted that all the exercises had confirmed that in favourable conditions existing British asdic equipment and weapons in the hands of a worked-up escort group were able to achieve a killing rate of about 30%, '...provided the target's speed [was] less than 12 knots.'[596] At higher submarine speeds the killing rate fell off to practically zero, perhaps exacerbated by the reputed poor handling qualities of the 6DF ships.[597] The A/S gear of these ships had been designed to deal with the wartime slow U-boats, and when a check exercise was conducted by *Battleaxe* and *Crossbow* against the slow HMS *Amphion*, the two ships achieved a 100% kill rate. Moreover, the exercises had each been carried out by ships growing in experience and confidence, but against different submarines with different characteristics, in different water conditions, and with different peacetime safety rules imposed. The overall results illustrate the complexity of the interactions between these factors:

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[595] 'A/S Practices of HMS *Battleaxe*, *Crossbow*, *Scorpion* and *Broadsword* with USS *Dogfish* in the North Channel in February and March, 1949,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274, pp. 74-75.
[596] 'The First Experiences of A/S Actions with Intermediate (B) Submarines...,' ADM 239/423, p. 2. [emphasis supplied]
[597] Leo Marriott, *Royal Navy Destroyers since 1945* (London: Ian Allan, 1989), p. 87.

Submarine	Chance of "surfacing damage" or a "kill"[598]
Selene	25.7%
Amberjack	15.4%
Scotsman	13.0%
Dogfish	32.3%

These figures also have to be taken in the context of peacetime safety rules. In wartime the submarine would be able to shoot back with anti-escort homing torpedoes. The exercises with *Trumpetfish* had demonstrated how an aggressively minded submarine could behave, but, on the other hand, the peacetime submarine could afford to behave more liberally, when '...the penalty for being detected was one hand grenade as opposed to a full pattern of depth-charges [or Squid projectiles]. The thought doth make the submariner prudent!'[599] The Admiralty pointed out, that during the trials off Key West, *Amberjack*'s battery had been in the fully charged state at the beginning of each A/S action, '...a state most unlikely to be met with in war.'[600]

During the long series of trials Captain (D), Sixth Destroyer Flotilla, had experimented with a number of tactical ideas for dealing with the Intermediate (B) submarine. The trials, the Admiralty concluded,

> ...have shown that whilst the ["Ring"] Co-ordinated Action is sound in theory, there are many practical difficulties in poor asdic operating conditions, and when wakes left by the submarine and A/S vessels are liable to persist. A submarine which uses high speed under these conditions is liable to elude the A/S ships forming the "ring".[601]

The highly dynamic tactical engagements with Madden's ships had turned most close A/S actions into stern chases, just as had been discovered by Captain Gibbs, Captain (D), Fourth Escort Flotilla, and against *Seraph* five years previously. As a result the tactics used were similar. Gibbs had formulated the "Umbrella" formation and had passed on his thoughts on to Madden, who, largely through extensive practice, was able to exploit the tactic to its full advantage {*Plate 23*}. Madden developed the idea that the attacking ship would follow roughly astern of the submarine, supported by wing ships at about 1,200 yards on either beam. When asdic conditions were poor, the wing ships were kept well up on the attacking ship's beam, where they were better able to maintain contact. In good asdic conditions the wing ships could afford to drop back a little, where it was easier for them to conform to the movements of the attacking ship or to take over that role should the need arise. The dynamic tactical situation could

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598 'The First Experience of A/S Actions with Intermediate (B) Submarines,' ADM 239/274, p. 53.
599 Vice Admiral Sir Lancelot Bell Davies, KBE, e-mail, 6 January 2001.
600 'Progress in Underwater Warfare, 1948,' ADM 239/422, p. 41.
601 'Progress in Tactics, 1949,' ADM 239/565, p. 27.

Plate 23: Four Ship Tactic (Umbrella)

'A/S Action,' Part 6, in, C.B. 04097 (1/51) and S.D. 697 (1/51), 'Conduct of A/S Operations by Ships and Aircraft,' T.A.S.W. 196/50, Admiralty and Air Ministry, 3 October 1951, Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 468, RG 38, National Archives and Records Administration 2, College Park, Maryland, p. 11.

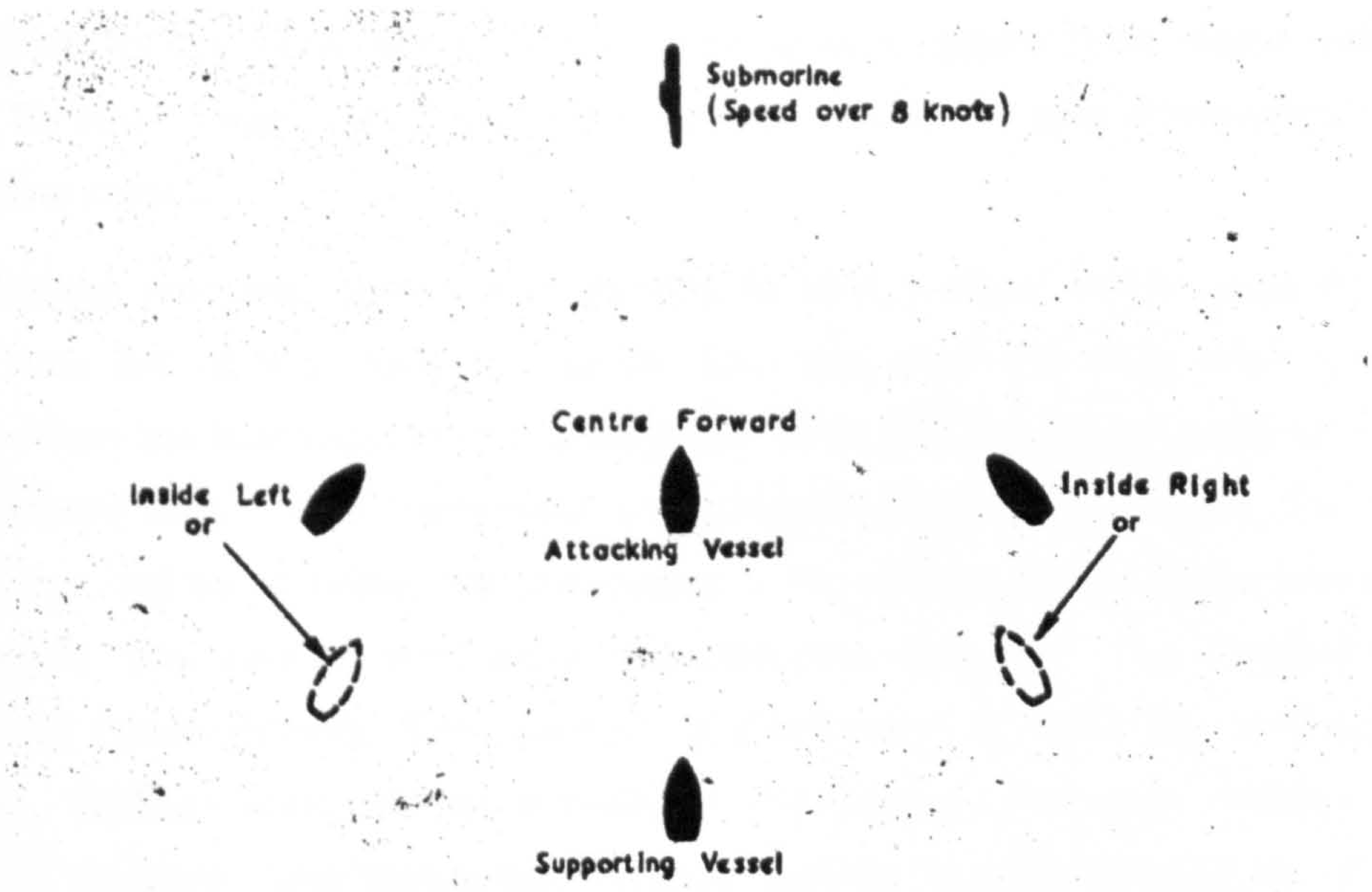


Fig. 3. DISPOSITION OF A/S VESSELS ATTACKING A FAST SUBMARINE

"Umbrella" (which can be compared with the formation used against *Seraph*) change from moment to moment and this formation allowed the duties of the attacking ship to be shifted to the best placed A/S vessel. This might happen, Madden had discovered, '...a number of times before a particular attack was consummated.'[602] When a fourth ship was available it was stationed about 2,000 yards astern of the leading ships, where it was well placed to cover against the submarine suddenly reversing course and breaking back through the lead ships, which *Trumpetfish* had used against 3EF. Once the submarine began to run out of "amps" and was forced to slow down, a loose "Ring" formation developed automatically. The highly practiced 6DF were even able to execute these tactics at night. Of course, in wartime it would rarely be possible for as many ships to be spared to concentrate on a single submarine. Tactics for two-, three- and four-ship formations were eventually incorporated into the A/S tactical manual.[603]

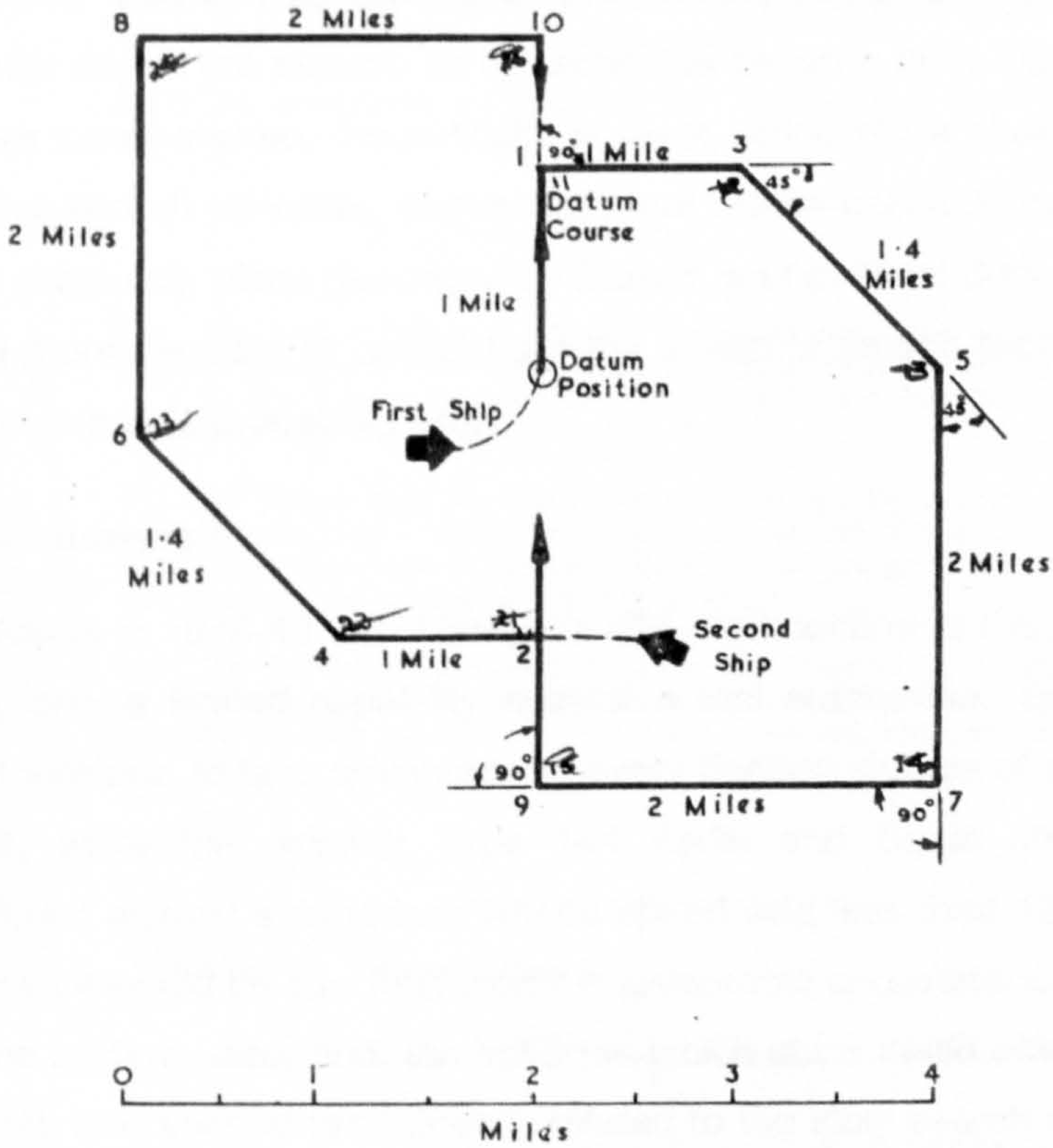
Madden had also given some thought to search plans which could be used if contact was lost during close A/S action. This was often the case after a series of attacks, when the manoeuvres of the attacking ships and the violent avoiding action by the submarine left the area "waked-up" and plagued with non-sub echoes. The moment contact was lost by all ships, the uncertainty in the submarine's position expanded at an alarming rate, and an immediate response was essential. This response would depend on circumstances. For example, if there were at least two to three ships available, Madden instituted an immediate lost-contact procedure initiated by the codeword "Cogitate", and developed from the wartime "Search Scheme No. 1" to take account of the acoustic signature of a high-speed submarine. Thus, all A/S ships reduced to slow speed and carried out two all-round listening sweeps for HE followed by one all-round echo sweep, starting on the side away from the last known position of the submarine. Meanwhile, the Senior Officer would be planning the subsequent search scheme if contact was not regained. With only two ships close at hand there was not time to carry out "Cogitate" and a start had to be made on searching the expanding probability area straight away.

Madden developed an experimental search that became known as Plan "Delta", which was a reduced version of the elaborate US Navy "Barndance" search. This should not be confused with the Plan "Delta" used in the trials with *Seraph* – that

602 'The First Experience of A/S Actions with Intermediate (B) Submarines,' ADM 239/274, p. 56.
603 'Conduct of A/S Operations...,' Box 468, RG 38, NARA2, Part 6, p. 9-12.

Plate 24: Plan Delta, 1950

Plan "Delta", c. 1950, H.M.S. *Vernon*, I.L. No. 659, 'T.A.S. Warfare Springback,' Lieutenant Commander J. H. Adams Royal Navy, Commanding Officer [H.M.S. *Creole*], 1 June 1950, Adams Papers.



version had been deleted from the tactics books by the end of 1945.[604] The new Plan "Delta" replaced the simpler "Box" Search {*Plate 24*}. Instead of a static square barrier, the idea now was that the ships started an outward spiral within 5 minutes of the loss of contact and searched along the submarine's FoC expanding at 15 knots. Towards the end of the search, the ships turned inwards to search the area nearer the datum, to cover the possibility that the submarine was either evading at low speed or by constant turns was thus still close to the datum. When three ships were available the more elaborate "Lambda" Search was used, still based on the same concept. As more ships became available to join the search, so the schemes became more complex but could also cover more water and so, theoretically at least, stood more chance of regaining contact.[605] These search schemes, somewhat more mathematical in concept, stood in contrast to the pragmatic plans described by Burnett and evolved during the war when it was deemed more sensible to concentrate the available search team on a selected sector of the submarine's probability area.

Technological Answers?

The exercises in 1948-49 with Madden's 6DF had confirmed that A/S ships had, as anticipated, only a limited capability against a fast submarine. Tactical methods were needed, therefore, to take advantage of every fleeting chance of a kill. As for the ships' systems, while the existing Type 144 Asdic and Squid combination was reasonably efficient against submarines whose speed was less than 12 knots, against faster submarines it would be successful only in favourable circumstances.[606] The main limitations of the system were, first, the speed at which ships could effectively operate the asdic was too low, second (and directly related to the slow search speed) the rate of asdic search was too slow and, finally, the accuracy of the fire-control solution was inadequate for the available ATW weapons. The ship's operating speed was critically dependent on the level of self-noise, which in turn, was determined by the interference from the ship's propellers and the design of the asdic dome. Research was underway into improved propeller designs and means of silencing existing propellers, and a new experimental asdic dome had already been fitted to HMS *Scorpion* during 1946, which allowed asdic operation at speeds of 25-28 knots (that is, 7-10 knots higher than

[604] 'Conduct of Anti-U-Boat Operations: Part IV, Air and Surface A/S Searches and Striking Forces,' DASW, ASW 3078/43, BR1679(4), June 1944, ADM 234/293; 'TAS Warfare Springback,' Lieutenant Commander J.H. Adams, Royal Navy, Commanding Officer [HMS *Creole*], 1 June 1950, Adams Papers.
[605] 'The First Experiences of A/S Actions with Intermediate (B) Submarines...,' ADM 239/423, pp. 19-28.
[606] 'Progress in Underwater Warfare, 1948,' ADM 239/422, pp. 40-41.

previously).[607] Improving the asdic search rate was partly dependent on the ship's speed and partly on the scanning rate of the asdic itself. This had been appreciated for some time and work was in hand to develop an all-round scanning asdic, but this would not be available for many years due to the technical complexity of the equipment, though a set capable of scanning over a sector was expected to be available by 1953.[608]

During the highly dynamic engagements against a fast submarine, inaccuracies were generated in the fire-control solution by the effects of the ship's manoeuvring. This error was removed by introducing the Ship's Component Mechanism to existing asdic installations.[609] However, errors were still induced by the slow rate of calculating the target's bearing with the wartime searchlight asdic sets using the "cut-on" procedure and the necessity of roughly pointing the ship at the target in order to fire an Ahead Throwing Weapon (made more difficult by the need to fire at a short, fixed range). Research had been underway since the early 1940s into the application of radar "Split-Beam" technology to asdic to produce instantaneous bearing and depth measurement. This technique was originally intended to improve the fire-control solution against slow, deep U-boats. When the fast submarine threat emerged, it soon became apparent that an effective solution consisted of the integrated use of up-to-date asdic bearing and depth accuracy with an improved A/S mortar (suggested by Prichard in DASW during 1944), capable of all-round training and firing at a variable range. These developments became the Type 170 (or "Four-Square") Asdic and the Limbo mortar, capable of firing Squid-like projectiles at variable ranges from 400-1,000 yards, and were experimentally fitted together in *Scorpion* in 1950. The probability of success with Limbo was high, although at the longer ranges against a manoeuvring submarine, its fire-control prediction induced errors because it was based on the assumption that the submarine was moving on a straight course.[610]

A programme was also underway to develop a ship-launched A/S torpedo, capable of homing onto a submarine at long range, though the British remained sceptical that the problems of homing in shallow waters could be successfully overcome and this torpedo took lower priority than development of these weapons for

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607 'Underwater Detection Establishment – Research and Development – Progress Report Number 2,' DTSR, 17 November 1947, NAA(M): MP1049/5, 1968/2/663; 'Half-Yearly Scientific and Technical Progress Report,' ADM 213/362; 'Fitting of High Speed Dome to Destroyers,' Ship Design Policy Committee, SDPC(49)14, 25 May 1949, ADM 116/5632.
608 ACNS to First Sea Lord, ACNS/263, 20 October 1948, ADM 205/69.
609 'Fitting of High Speed Dome to Destroyers,' ADM 116/5632.
610 'HMUDE Summary of Progress,' 1 December 1948, NAA(M): MP1049/5, 1968/2/800.

aircraft use.[611] The timings for these technical improvements neatly matched the forecast in the Short-Term and Long-Term policy set out by Ashbourne in 1946. The major step forward was the integration of this equipment, initially in frigate conversions, and later into new ship designs.[612] The detailed requirements for the conversions were worked on by Burnett and Ormsby and eventually evolved into the first Type 15 Frigates, *Rocket* and *Relentless* allocated to Third Training Flotilla under Captain Le Fanu.[613] Even with improved asdics, action information centres, the limbo mortar and high ship's speed, exercises with fast submarines were beset with difficulty. The number of practices, Le Fanu noted, had '...not been plentiful but we have had some duels with *Turpin*...[but] *Turpin* won on a technical knockout.'[614]

The outlook for aircraft still remained gloomy, though the use of MAD and equipment to detect the intra-red or ionised properties of schnorkel gases were at various stages of development.[615] However, the principle methods of locating submarines remained visual or radar detection of the schnorkel head and sonobuoy detection of the acoustic signature. Little could be done to improve visual detection, other than by providing better sighting positions for the crews in aircraft. British research towards the end of the war had concentrated on attempts to use high-frequency radars to reduce the effects of sea clutter.[616] In the post-war era, varying interest was shown in the US development of high-powered AEW radar to detect schnorkels. USN aircraft on tour of Britain in mid-1948 had been able to detect a schnorkel at ranges of 17-23 miles in sea states 2-3. However, when the sea state rose to 4-5, which was commonplace in British waters, the number of detections was considerably reduced by the interfering effects of sea clutter. For the smaller carrier-borne aircraft, such as the Avenger, carriage of the heavy AEW radar meant that a separate aircraft had to localise and attack any contacts achieved.[617] The sonobuoys in

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611 'Report on 10th TAS Liaison Meeting – HMS *Vernon* – 18-20 September 1951,' Lieutenant Commander M.S. Batterham, RANVR, 9 October 1951, NAA(M): MP1049/6, 5036/32/140.
612 'Underwater Weapons and Equipment – Research Reports – Summary,' DTSR, 28 April 1949, NAA(M): MP1049/5, 1968/2/780.
613 Mosse, 'Half a Lifetime,' p. 76; 'Joint Anti-Submarine School, Londonderry. Progress Report – Summer Term, 1952,' C-in-C, Plymouth, M.024475/52, ADM 1/23733, pp. 7-10.
614 'Eleventh TAS Liaison Meeting: Minutes,' Part 4, 'Evaluation of Fast A/S Frigate Conversions,' paper read by Captain M. Le Fanu, DSC, RN, Captain (D), Third Training Squadron, 9-11 September 1952, ADM 189/235, p. 37.
615 'Admiralty Research Laboratory and Admiralty Gunnery Establishment, Teddington: Statement of Work in Hand – August 1945,' NAA(M): MP1049/5, 1968/2/577.
616 Llewellyn-Jones, 'British Responses to the U-boat,' p. 17.
617 'Summary of Operations Aircraft Development Squadron Four Detachment in the United Kingdom during the Period 26 May to 17 June 1948,' F.E. Bardwell, Commanding Officer, Aircraft Development Squadron Four, to Chief of Naval Operations, VX-4/A4-3 Serial: 005, 1 September 1948, Box 97, RG 313, NARA2; 'Joint A/S School Exercises,' The Commanding

use were of wartime design and remained limited in range. Their capability would not be improved substantially until Very Low Frequency (VLF) acoustic techniques could be applied to them, and the technological advances needed would not provide results for many years.[618] The provision of homing torpedoes for aircraft attacks on submerged submarines struggled against great technical difficulty.[619] Even so, work continued optimistically to analyse the potential of aircraft used in offensive operations over submarine transit routes. It was clear that if any appreciable level of performance was to be achieved a wide selection of the sensors and weapons under development would have to become operational in the new aircraft, such as the land-based Shackleton and carrier-borne Gannet.[620] The first tentative steps with the use of helicopters for A/S operations had been made by a joint Anglo-US team in 1943, but had foundered on the poor operational performance of the machines. Nevertheless, attention continued to be directed (mainly in America) to the development of an A/S helicopter capable of carrying a "dunking" asdic. This appeared to show considerable operational benefits, though these, too, would not be realized for some considerable time.[621]

British submarines had sunk 17 and 40 U-boats in the First and the Second World Wars respectively, but this had not been their primary role. All bar one of these successes had been against U-boats operating on the surface. The one exception was HMS *Venturer* in early 1945, which sank *U-864* in an engagement during which both submarines were submerged throughout.[622] The idea of making A/S warfare the primary role of British submarines was initiated in early 1946 by [then] Commander A.R. Hezlet, DSO*, DSC, the submariner on DTASW's staff.[623] Burnett followed up the idea in his paper on future anti-submarine problems during the following year. British submarines, working in the same medium as their prey might be operated to advantage, however, they would have

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Officer, 19 Carrier Air Group to The Commanding Officer, HMCS *Magnificent*, 28 May 1948, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

[618] 'The Application of Lofar Techniques to Sonobuoys,' D.A. Hanley, UDE Pamphlet No. 293, September 1953, ADM 259/205.

[619] 'Anti-Submarine Tactics and Training,' Squadron Leader R.J. Wilcock, RCAF, for Air Member, Canadian Joint Staff, London, S25-28 (Armament), 3 April 1951, File S-28-1-4, Vol. 5270, RG 24, NAC.

[620] 'Transit Offensives and the Inshore U-boat,' I.E. Tweedie, Department of Operational Research, Report No. 29, August 1953, ADM 219/607.

[621] R.A. Brie, 'Rotary-wings at Sea,' *The Aeroplane* (6 July 1951), p. 25 'Third A/S Tactical Liaison Meeting held in HMS *Vernon* on 1st and 2nd May 1947,' A.198/3/47, 17 May 1947, distributed by Op-32-F-45, n.d., Box 102, RG 313, NARA2.

[622] 'HMS *Venturer* – Report of Eleventh War Patrol,' Lieutenant J.S. Launders, RN, No. SC 4110, 15 February 1945, ADM 199/1815.

[623] Vice Admiral Sir Arthur Hezlet, KBE, CB, DSO*, DSC, Telephone Interviews, 22 and 23 September 2000; *Navy List* (3), January 1946.

> ...to be fitted with a means of detecting and locating submerged submarines. Although submarines may prove to be more efficient vehicles for the asdic than surface ships, the comparatively short ranges of asdic will limit their usefulness on patrols. Also some form of recognition equipment have to be developed before they can be operated effectively in waters used by other A/S forces.[624]

These ideas were developed by the end of 1947 into papers on the use of submarines as A/S vessels. The idea of using submarines as convoy escorts proved to be stillborn, largely due to the problem of mutual recognition between friendly forces.[625] However, the more promising idea of their use as part of the forward attack-at-source strategy in enemy controlled waters had a strong pedigree and considerable potential for the future not only for laying mines off their ports but in direct attacks on their submarines. The technical and tactical problems, which took a long time to be solved, were the submarine's ability to locate its target at long range (using VLF acoustic techniques), and then to close to an attack without alerting its prey (requiring long endurance at a high silent speed) and, finally to attack with homing torpedoes which could overcome the problem of target depth and evasive manoeuvre. Streamlined, snort-fitted submarines were limited by underwater endurance, and, for a while, it was hoped better performance could be achieved by adapting the HTP submarine developments already in train.[626] Sufficient optimism in the potential of submarines encouraged the Admiralty to announce in early 1948 that:

> In war, the primary operational function of our submarines will be the interception and destruction of enemy submarines in enemy controlled waters.[627]

The "Iron Curtain"

Much of this development was conducted against a background of a hardening political and military threat from the Soviet Union. The political realization of the aggressive extent of this threat had been hesitant. The Americans, in particular, greeted Churchill's "Iron Curtain" speech in March 1946 with little enthusiasm.[628] The British, too, wanted to work in harmony with both America and Soviet Russia in the immediate post-war era. However, problems soon developed. 'The work of the

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[624] 'Anti-Submarine Problems of the Future,' AIR 20/6381, Part 5.

[625] M. Llewellyn-Jones, 'A Flawed Contender: The "Fighter" Submarine, 1946-1950,' in Martin Edmonds (ed.), *100 Years of the Trade: Royal Navy Submarines Past, Present & Future* (University of Lancaster: Centre for Defence and International Security Studies, February 2001), pp. 58-67.

[626] 'Requirements for an HTP Operational Submarine,' Flag Officer Submarines 705/S/M.068 dated 8 September 1952 with Notes by Admiralty Divisions and Departments,' [DTSD, 12 November 1952], ADM 1/23729.

[627] N. Abercrombie to Commanders-in-Chief and Flag Officer (Submarines), etc., M.TASW.289/47, 8 January 1948, ADM 1/24407.

[628] Norman Friedman, *The Fifty Year War: Conflict and Strategy in the Cold War* (Annapolis: Naval Institute Press, 2000), p. 60.

quadripartite administration in Germany,' Clement Attlee later wrote, 'was frustrated constantly by Russian intransigence, while at [the United Nations Organization] the Russian representative soon showed his intention of abusing the Veto.'[629] The Americans soon became disillusioned with their prickly wartime ally, and this had the effect of drawing them closer to the British. It was the issue of Marshall Aid in 1947, proposed by the US and instantly supported by Britain, but rejected by the Russians, that dashed hopes for the integration of Europe. The Russian rejection was one stage in the gradual hardening of the political division of Europe over this period and marked another hesitant step into the "Cold War".[630] Attlee soon realized that military strength was the only factor which impressed the Russians. Even so, war-weariness amongst all the wartime allies, including the Soviet Union, as well as the American monopoly of the atomic bomb, made all-out war unlikely in the near future.[631] The JIC concluded that while the Soviet Union ultimately sought World domination, she would, at least in the near term, rely on a "Cold War" strategy, short of all-out war.[632] There was not, however, a sudden schism between the wartime German threat and the new Cold War Russian menace. By 1948, as Sir Percy Cradock, a one-time chairman of the JIC, noted:

> The Berlin blockade is in place. The two superpowers confront one another, each with its attendant states and its military and economic groupings. This is the Cold War as popularly understood. But, as the records show, it was preceded by a more fluid and uncertain period, which saw the transformation of Russia from heroic wartime ally to principal enemy....[633]

Indeed the fledgling Ministry of Defence developed the "5+5 Rule" which assumed that the risk of war over the next 5 years was negligible, that is, up to about 1952, but would increase thereafter.[634] The Anglo-American political relationship was by no means assured, though at the working level of the Naval Staff co-operation with the Americans was close, as had been shown by the constant liaison visits by DTASW staff officers and the major visit by Admiral Styer in early 1947.[635] VCNS had also recently had a visit from the USN Deputy Chief of Naval Operations

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629 C.R. Attlee, *As it Happened: His Autobiography* (London: Heinemann, 1954), p. 170.
630 Michael Dockrill, *The Cold War, 1945-1963*, (London: Macmillan, 1988), pp. 34-51.
631 'Certain Assumptions for Planning Purposes,' Report by the Joint Intelligence Sub-Committee, JIC(46)19(0)(Final), 6 March 1946, CAB 81/132.
632 Peter Hennessy, *The Secret State: Whitehall and the Cold War* (London: Allen Lane, 2002), p. 18.
633 Percy Cradock, *Know Your Enemy: How the Joint Intelligence Committee Saw the World* (London: John Murray, 2002), p. 29.
634 'Assumptions as to Risk of Future War and Target Date for Re-equipment of the Fleet,' 1947-1948, ADM 116/5966.
635 Moore, *Royal Navy and Nuclear Weapons*, p. 42; A.B. Birnie to M.M. Low, A/M.01938/46, 1 March 1948, AIR 2/12249.

> ....who had told him that the USN were now giving highest priority to anti-submarine problems, and were anxious that there should be complete interchange of information with the Royal Navy in such matters.[636]

British and Allied Tactical Doctrine

The tactical use of these A/S units was enshrined in national and allied tactical publications which owe a strong debt to the earlier doctrine developed by Burnett and his team in the first days of peace.[637] These ideas were to form the basis of Allied doctrine for what can now be seen as modern anti-submarine warfare. The doctrine manuals of the 1950s confirmed the integrated offensive and defensive approach to A/S warfare formalized by Burnett, his team and their successors in the Admiralty in 1946-48, which itself had followed the basic precepts developed during the 1930s and in the heat of the Second World War. At the strategic level a series of Allied planning meetings were held in Washington during October 1949 which produced the revised plan "Galloper" outlining Allied strategy in the event of war with the Russians up to mid-1951. By this stage it was assumed that the Russians would have a limited number of atomic bombs (as well as limited stocks of chemical and biological weapons). The planners realized that Allied strategic alternatives were bounded by their military capabilities which, initially, was extremely limited.[638] In broad terms this reduced Allied options to the launching of an immediate strategic air offensive (using atomic bombs) from land and sea. Vital base areas would also have to be defended, as well as the sea and air communications used to support these attacks and to maintain the flow of supplies while the Allied strength was being mobilised. The British had already made it plain that simply defending sea communications was in itself inadequate and the planning had to encompass offensive operations and attack-at-source in the North Atlantic area.[639] The enemy was expected to make his main assault on Allied sea communications by attacking ports and their approaches by mining, inshore submarine attack, bombing and sabotage. That said, the primary means of shipping protection at sea remained the imposition of convoy to deal with both the submarine and air threat, though the linkage of use of convoy against the mine threat was not made. As for the submarine threat, this was expected to be strongest in the inshore waters of the

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[636] 'Joint Sea/Air Warfare Committee: Minutes of the 2nd meeting of the Committee held at the Admiralty on 27 August 1946,' SAWC 2/46(12), 27 August 1946, AIR 20/6842.
[637] 'Conduct of A/S Operations...,' Box 468, RG 38, NARA2; 'ATP1 [Allied Naval Maneuvering Instructions], Change 1: January 1952,' Box 4, RG 38, NARA2.
[638] 'Plan "Galloper",' Chiefs of Staff Committee, Joint Planning Staff, JP(49)134(Final), 1 March 1950, DEFE 6/11, p. 7.
[639] 'Strategic Guidance from the Standing Group to the Regional Planning Groups on the North Atlantic Treaty Organisation,' Chiefs of Staff Committee, Joint Planning Staff, JP(49)149(Final), 21 November 1949, DEFE 6/11.

western approaches to the United Kingdom. This was the plan which, the Chiefs of Staff believed, showed how the Allies would have fought if general war had broken out as a result of the conflict in Korea.[640]

At the end of 1948, during a visit to America, Admiral Rhoderick McGrigor, Commander-in-Chief, Home Fleet, in a discussion with the Admiral McCormick, US Commander-in-Chief, Atlantic, came to the mutually agreed position

> ...that provision of escorts for convoys should take precedence of formation of hunter/killer groups. When it is possible to form these they may initially have to be confined to dangerous areas where they can be used in close support of convoys.

The two Admirals also agreed

> ...that the safe and timely arrival of the convoy must still be the Escort Commander's objective and not the hunting to death of the attacking U-Boat at the expense of the convoy....[641]

This apparently defensive philosophy was agreed against an expectation that a wholly inadequate number of escorts would be available in the opening phase of a future war. McGrigor's overall view became clear during Fleet exercises. During the early spring of 1949, amidst appalling weather more characteristic of winter conditions, the Home Fleet carried out Exercise "Sunrise" in the North Atlantic during which McGrigor put into practice the latest A/S doctrine. Notwithstanding the limitations imposed on all the players, the C-in-C observed that: 'In spite of the difficulties of locating and destroying the modern fast submarines, ...the policy of employing hunting groups [was]...based on firm foundations.' However, he added, that

> Until...a more efficient form of detection is developed for carriage in aircraft, it is probable that the majority of submarine "kills" will take place in the vicinity of the convoy or main body with which the hunting groups are working.[642]

McGrigor's observations were based on the widespread understanding of the inter-dependence of the "defensive" and "offensive" in A/S warfare. The "Patrol" or "Hunting" Group was intended to work with, and not independently of, the main body of the Fleet, though at some distance ahead. The idea chimed well with Admiralty views and indeed echoed the proposals for the employment of Patrol Groups propounded by DTASW at this time, and the use of support groups during the war. The practical problem of

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[640] Eric Grove and Geoffrey Till, 'Anglo-American Maritime Strategy in the Era of Massive Retaliation, 1945-60,' in John B. Hattendorf and Robert S. Jordan (eds.), *Maritime Strategy and the Balance of Power: Britain and America in the Twentieth Century* (Basingstoke, Hants.: Macmillan Press, 1989), p. 276.
[641] Admiral R. McGrigor, Commander-in-Chief, Home Fleet to Admiral of the Fleet Lord Fraser of North Cape, First Sea Lord, 24 November 1948, Section 5, ADM 205/70, p. 3.
[642] 'Remarks by Commander-in-Chief, Home Fleet,' Enclosure No. 6 to 'Exercise "Sunrise",' Admiral McGrigor, Commander-in-Chief, Home Fleet, No.393/940/105/10, 28 March 1949, ADM 116/5779.

carrying out these "offensive" tactics was the lack of resources and not any lack of aggressive thinking. In spite of the anticipated shortage of A/S vessels and aircraft at the beginning of a war, McGrigor believed that, exercises should be carried out to perfect the techniques for A/S hunting groups.

"Sunrise" was also intended to simulate operations against the threat of atomic attack, and illustrated the difficulties this would pose. While atomic attack was not a serious threat to the Fleet at sea, the threat did require ships to be stationed further apart than hitherto, which complicated inter-ship communications and diluted the A/S defence. When this was compounded with the problem of long-range torpedo fire from enemy submarines, which might be gaining their initial intelligence at a range of some 20 miles, it is not difficult to see why the stationing of a Patrol Group some 20-25 miles ahead and on either bow of the Fleet was attractive, where enemy submarines might be exposing their radar mast while trying to locate the Fleet. Exercise "Verity", carried out later in that year, included convoy serials, which illustrated the pressure for as many ships and aircraft to be involved and to benefit from the training, but it also showed the downside by the consequent lack of realism, with too many escorts crowded round the convoy. The exercise also saw the use of the French *U-2518* though the level of success by the attacking submarines operating singly was largely dependent on the environmental conditions.[643]

Exercise "Trident", really a conference, was held at the Royal Naval College, Greenwich, in April 1949. The invitation to the conference announced that it was designed to apply the lessons of the Second World War to a possible war in 1956-57, taking into account scientific and technical developments. In his forward to the conference pack, the First Sea Lord, Lord Fraser, noted that they were in a period of transition and that new weapons were the order of the day. When war might occur, and what would be the state of weapon development no one could say. 'In such circumstances,' Fraser went on,

> ...the task of the Admiralties is not a simple one and it is hoped through this Exercise to inform the Fleets fully of the lines on which the Naval Staff in London is working and thereby establish principles which will assist in the solution of some of the problems confronting us.[644]

So, "Trident" set out to inform and provoke discussion. It was designed to illustrate how maritime forces might be operated in 1957 and the importance of offensive action, within a defensive maritime strategy was to be emphasized. The likely problems which

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[643] 'Monthly Intelligence Report, July 1949,' NID, 10 August 1949, DHH.
[644] 'Exercise "Trident", Volume I,' CB004520, April 1949, ADM 239/489, p. iii.

could be encountered in supporting the Army and Air Force were to be covered, but particular attention was to be paid to the defence of shipping. All the operations were to be compressed, somewhat artificially, within a single strategic setting six months into a war with Russia. The British therefore found themselves '...in the throes of the Third Battle of the Atlantic.' Once more a major national effort was focused on the conflict which was expected to be as deadly as its two predecessors, mainly because, it was assumed, the Russians would be equipped with the latest refinements of submarine warfare. This threat had '...temporarily out-run the counter-measures necessary to combat it....' The Russians would also make extensive use of submarine minelaying.[645]

Commanders Barley and Titterton and Lieutenant Commander Waters in the Historical Section of the Naval Staff, had been almost entirely occupied during the first three months of 1949 in research work for Operation "Trident". They had produced narrative and statistical appreciations of the various aspects of the war, much of which was used in the planning of the Exercise.[646] During the first sessions of the Exercise, the President of the Royal Naval College, Greenwich, Vice Admiral G.N. Oliver, lectured on the defence of ocean shipping. He was a Gunnery officer with no experience of the Battle of the Atlantic, so, before he addressed the conference Oliver had obtained a briefing from the Historical Section. He was not entirely uninformed, for he had recently relinquished his appointment as ACNS, a post he held while many of the anti-submarine doctrine papers were being drafted by the Naval Staff, including the comprehensive survey on the "Anti-Submarine Problems of the Future" and the subsidiary study on "Attack-at-Source and Harbour Defence". In his presentation, Oliver argued at some length on '...the absolute value of convoy.' He also felt it necessary to remind the audience that: 'In our very natural zeal for direct action, let it not be forgotten that the escorting of shipping in convoy is not merely a defensive and negative process.' With guidance from the Historical Section, Oliver also noted that wartime Hunter-Killer group operations had achieved comparatively little, though air patrols over the U-boats transit routes had had considerable success. Nevertheless, he pointed out, it was the convoy escorts, both surface and air, which destroyed more German U-boats '...than any other single means of attack,' according to figures supplied by the Historical Section.[647]

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[645] 'Exercise "Trident",' ADM 239/489, p. xiv.
[646] Grove (ed.), *The Defeat of the Enemy Attack on Shipping*, p. xvi; 'Historical Section of TSD – Review of Narrator Posts, Roger M. Bellairs, 11 November 1949, T.27309, NHB.
[647] 'The Defence of Ocean Shipping in 1957,' Vice Admiral G.N. Oliver, CB, DSO, President RN College, Greenwich, Item 17, in, 'Exercise "Trident",' ADM 239/490, p. 85.

The "Trident" Directing Staff (reflecting Naval Staff opinion) agreed that both world wars had proved that '...the most fruitful areas for sinking enemy submarines were in the vicinity of convoys,' adding the proviso, that the escorts had to be '...sufficient in numbers to allow detachments for killings.' However, while the Staff had already noted that '...defensive measures for protection of our shipping must be maintained and if possible increased,' but these, the Staff concluded, '...will not themselves suffice....' This was because the British

> ...economic position before the war has not admitted the building up of our maritime Escort Forces to the desired strength, nor has the technical and scientific advance in our equipment run parallel with the progress made in the evolution of the submarine.[648]

It was the latter of these problems, which the Directing Staff considered to be most significant. By 1957, they pointed out, submarines would still be difficult to locate, especially from the air. Consequently, the concept of "Attack-at-Source" came into greater prominence than before. This was '...a familiar and self explanatory term...' and referred to attacks on enemy ports, naval bases, and so on, by carrier-borne or shore-based aircraft, by "sneak" craft, commando raids and so on. These attacks were complemented by "Offensive Control" consisting of offensive minelaying, offensive A/S air patrols, the interception of submarines on their transit routes by Hunter-Killer groups, attacks by our submarines in enemy controlled waters, and attacks on enemy surface forces, particularly minesweepers. There remained a requirement for "Defensive Control" including the close escort of convoys by surface forces (with aircraft carriers), shore-based fighters and A/S aircraft, as well as defensive minefields, and so on.[649] These methods were explored further during the Exercise, though the "defensive" convoy escort task received more than twice the attention as did the "offensive" and "attack-at-source" tasks together.[650]

The "Trident" Directing Staff also interpreted the Historical Section's data in a different way to show that roughly equal numbers of U-boats were sunk by "offensive" as "defensive" measures. For reasons which are not entirely clear. The Historical Section laboured under the impression that the Naval Staff was led by the "convoy is defensive" school, and were bent on shifting to an all-out "offensive" anti-submarine

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[648] 'Exercise "Trident",' ADM 239/489, p. xiv.

[649] 'A Survey of the Tasks of the Maritime Forces in Support of the Three Pillars of Our Strategy,' Item 13, in, 'Exercise "Trident",' ADM 239/489, p. 25.

[650] 'A Joint Planning Staff Conference before the Outbreak of War,' Item 28, and 'The Defence of a Convoy against Submarine Attack: Demonstration by the RN Tactical School,' Item 30, in, 'Exercise "Trident",' ADM 239/490.

strategy.[651] Their staunch advocacy of convoy re-surfaced in a Research Memorandum in 1952. The bulk of this work was readily accepted by the Naval Staff, but as Captain V. Donaldson, the new DTASW, noted it concentrated too heavily on convoy, failed to take account of other measures and, worse, summarily dismissed the period of the inshore campaign in 1944-45.[652] It was, of course, operations against the schnorkel-fitted U-boats and the incipient threat of the fast U-boats which most influenced the post-war anti-submarine warfare Staff, and not the convoy battles of 1942-43 against the wolf packs. When the period of these great convoy battles is compared with the last inshore campaign, the proportion of U-boats destroyed by surface escorts fell from 43% to 17%, and by air escorts from 22% to 9%. Between the same periods, the effectiveness of sea patrols increased from 4% to 12%, and bombing rose from 0% to over 12%.[653] The Naval Staff concluded – as Fawcett had prophesised – that precision killing around convoys would no longer be adequate. Other methods, however inefficient, had to be tried. The historians failed to discern this change between the mid-war and late-war A/S campaigns.

It was against the background of "fluid" politics but more assured naval co-operation with the Americans, that the Admiralty was drafting its doctrine papers to deal with the fast submarine threat – a doctrine which owed its pedigree to the concepts developed during the inter-war period and wartime operations. It was the fundamental holistic relationship between the defensive and the offensive that was key, rather than the idea of these aspects as alternatives. The holistic concept underpinned the construction of the "Trident" conference. Convoy was seen as an essential element, because it cleared the ocean of multiple targets and complicated the submarines' reconnaissance and intercept problems. Submarines could operate in focal areas where convoys were easier to locate by individual submarines, but where anti-submarine forces would also be concentrated. Otherwise, submarines were faced with the problem of finding their prey in the open ocean, and of moving, probably at high speed, to intercept convoys. Wherever they operated, fast submarines would be more elusive targets than their predecessors, though when moving at speed they presented more detection opportunities to anti-submarine forces. The Admiralty's faith in offensive operations can, in part, be explained by their early knowledge of the highly secret "Corsair" and "Lofar" Very Low Frequency acoustic systems, which by 1949 could

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651 'The Convoy System: "Offensive or Defensive"?' Commander F. Barley and Lieutenant Commander D.W. Waters, Historical Section, Admiralty, December 1954, NHB.
652 Minute by Captain V.D'A. Donaldson, DTASW, 13 October 1952, ADM 1/24139.
653 'Historical Research Memorandum No. 1: Surface and Air Anti-Submarine Escort of Shipping in Convoy, and Anti-Submarine Transit Area Patrols in Two World Wars,' Historical Section, Admiralty, May 1953, ADM 1/24962, Table V.

locate submarines at tens, perhaps hundreds of miles. Fixes could be used rather like the wartime HF/DF system to vector anti-submarine forces onto enemy submarines.[654] Similarly, the greater emphasis on attack-at-source only made sense if it was predicated on the acquisition of lightweight atomic bombs and the aircraft to carry them. Ultimately, the sheer difficulty of locating and attacking submarines meant that every opportunity had to be taken to sink them. Only by destroying enemy submarines in sufficient numbers could they be forced to operate so circumspectly, that the safety of shipping could be reasonably assured. This meant that "offensive" action was needed from the defensive boundary of convoys to the heartland of the enemy and a complement to, not a replacement for, "defensive" convoy escort.

[654] Norman Friedman, e-mail, 17/05/02 16:26:11 GMT; 'Sub-sonic Hydrophone Investigation,' Admiralty Research Laboratory, Teddington, ARL/N.5/95.27/D, 31 August 1949, ADM 204/2841; 'Long Range Detection of Submarines using VLF Hydrophone Equipment,' DTASW, 20 June 1952, ADM 1/24506.

Conclusion: Joining up the Dots, 1944-1949

The Nature of Anti-Submarine Warfare

Captain P.W. Burnett, DSO, DSC, arrived at the Admiralty in September 1945, and was followed a month later by Commander G.A.G Ormsby, DSO, DSC, and Lieutenant Commander J.P. Mosse, DSC. These men were all A/S specialists, who brought to the Admiralty extensive wartime operational experience that was invaluable in their drafting of the doctrine papers which defined the way in which the British intended to deal with the threat of the fast submarine. From the time they completed their A/S specialist training and throughout the Second World War, they had studied and grown to understand A/S warfare. The submarine had inherently weak defensive qualities, and therefore relied on remaining undetected. Stealth was also crucial to its chance of making a successful attack with the relatively short-range torpedoes that were initially available. Denying the submarine the benefit of stealth was critical in order to prevent the submarine from attacking, an piercing the submarine's stealthy shroud was a prerequisite to destroying it. Fundamentally, as one experienced A/S practitioner had put it, A/S warfare revolved around '...an attempt to sink an invisible enemy by a sense which is not in every day use.'[655] By this he meant that, unless the submarine could be caught on the surface, detection relied on the use of asdic, and that equipment relied on the interpretation of complex sounds. There were two ways of doing this. In one the asdic was used to listen for the sounds produced by a submarine. Given the technology of the 1930s and 1940s, this meant that the main source came from the submarine's propeller noise, and was critically dependent, therefore, on the submarine's speed being sufficiently high. The most often used alternative was to rely on detecting the echo returning from an active transmission by the asdic set. These echoes were weak owing to the losses in transmission of the sound and the smallness of the submarine's echoing area. Their detection was made even more difficult by the reception not only of unwanted echoes from the seabed, wrecks and rocks, the sea surface, the body of the water (i.e. reverberations), but also extraneous sounds from the A/S ship's own movement through the water (i.e. self-noise). Classification of asdic contacts into "submarine" and "non-sub" categories was therefore often difficult and time-consuming.

[655] Anti-Submarine Training,' ADM 205/3. See Appendix 2.

Although the early submarine's underwater speed was low (generally less than 5 knots) the dynamics of an A/S action could nevertheless be high for two interrelated reasons. The range of initial detection was usually very short, in the order of half-a-mile, which gave the ship very little time before it overran the contact or the ship passed outside the detection range. Even at the short range-scales at which the asdic was transmitting, the speed of sound (very much lower than radar waves) meant that target data arrived in the ship at best at intervals of several seconds. Added to this was the intermittency of the received echoes due to the vagaries of the sea's structure and interference from reverberations and self-noise. Even when asdic contact was firmly established the problems did not abate. Measuring the range to the target was relatively straightforward, but establishing its bearing involved a time-consuming "cut-on" procedure. Estimating the target's depth was wholly guesswork until the introduction of a specialized depth-finding asdic (Type 147B), and even then depth measurement was inherently prone to errors because the sound beam was usually bent by the ocean's complex temperature structure.

Attacking the submarine with depth-charges was also fraught with difficulty. Initially, attacks required the A/S ship to pass directly over the aiming point, which was itself some way ahead of the submarine to allow for the time taken by the depth-charges to sink to the target's depth. During the last stages of the attack either contact was lost (if the submarine was deep), or the bearing rate accelerated as the ship passed ahead of the submarine. In either case, the estimation of the submarine's position, course, speed and depth, became less certain and resulted in the need for a barrage attack with multiple depth-charges in an attempt to overcome the three-dimensional aiming errors. The introduction of ATW, together with an integrated semi-automated aiming and firing system, removed many of these limitations. The advantages of ATW were, however, severely curtailed by the advances in submarine speed from 1944 onwards.

Before the operational appearance of the fast submarine, the enemy had already adopted schnorkel technology which allowed U-boats to operate continuously submerged throughout their war patrols. Large area searches by aircraft (for which they were uniquely suited) and which relied on detecting U-boats travelling on the surface, were instantly nullified. At the same time A/S ships had to revert to asdic as their main means of detecting the U-boats, and this forced them rapidly to review their tactical countermeasures. The U-boats, too, suffered from considerable limitations as a result of their new operating techniques, not the least being their ability to find and close targets. Fortunately, the schnorkel-fitted submarine problem bore strong resemblances to the threat posed by submarines at the end of the First World War, the interwar period and the opening phases of the Second World War. It was possible, therefore, to adapt existing tactical practice (albeit with the much improved equipment available) to counter this "new" threat. Against the conventional schnorkel-fitted U-boat at the end of the Second World War, a "blood-and-guts" confirmation (by way of wreckage) of success in the "new" procedures was possible, but against the fast submarine the British had to rely on trials and exercises whose realism was compromised by safety restrictions, even in wartime. Conclusions over the ultimate efficacy of tactical measures proposed for defeating fast submarines was therefore problematic. The overall difficulty of A/S warfare underpins much of the rationale for decisions over A/S developments that were undertaken not only, but especially, between 1944 and 1949.

The Nature of the Threat

By 1944, the submarine threat was immediate and (potentially at least) critical. This had not always been the case. For much of the interwar period, the threat from the German U-boat was meagre and only as war approached did the problem become urgent. The Royal Navy therefore adopted a stance of preparedness. This was, in many respects, repeated in the immediate post-war era when the potential threat now came from the Soviet Union. She had been ravaged by the Second World War and, in any case, had no real capacity to mount a submarine campaign against British trade or military operations. This threat, which was forecast (fairly accurately) to become serious by the late 1950s, would resemble that posed by the nascent threat of the German schnorkel-fitted high-speed U-boats which had been preparing for operations as the Second World War came to a close. The way in which post-war A/S warfare was conceived, therefore, owes more to the operations of the late war inshore campaign, than to the great convoy battles of 1942-43 against U-boats operating in packs and relying on surface travel for search and concentration around convoys. Because the Russian danger, in terms of actual operational capability (if not of political aspiration) was only just emerging in 1945-49, the threat against which the Royal Navy prepared was a generic one formed by an amalgam of the physical potential of the ex-German Type XXI fast U-boats, together with assumptions regarding corrections of German wartime operational mistakes (such as their failure to provide adequate supporting air reconnaissance). Nor did the reality of the atomic bomb create much impact, partly because the enemy had none, and partly because when they acquired some weapons, the numbers and power of the bombs was not initially thought to ensure the destruction of the will to fight. On the allied side, the possession of the bomb gave additional impetus to considerations of the efficacy of attacking enemy submarines at source. The resultant doctrine flowing from all these reflections seems to have served its purpose, since it remained broadly in use for the next two decades.

Tactics and Technology

Technological measures to counter either specific submarine developments or to overcome difficulties with existing equipment took many years to come to fruition. Thus there was no ready technical answer to the fast submarine and the Royal Navy had to adapt tactical procedures to maximise the potential of existing equipment in dealing with the new threat. Indeed, Burnett concluded that the metric for measuring the Royal Navy's and the enemy's operational facility was to match existing British A/S capability with that expected of the enemy's submarines 15 years hence. The long development cycle for new technologies, meant that they cannot be seen merely as emanating from some particular operational requirement. For example, the asdic development (Type 170) which did much to overcome the problem of accurately locating a fast submarine during an attack, began as a means of substantially improving the attack accuracy of depth-charge attacks against a slow, deep submarine. In the meantime, tactical adaptation led to procedures to overcome the original problem (the Creeping Attack), while the combination of existing asdic (Type 144) along with ATWs gave some capability against the emerging fast submarine problem. Tactical adaptation, rather than wholly new tactics, made sense because existing tactics were familiar (thus reducing the re-training load) and, in any case, were interrelated with the equipment which was still to be used. Moreover, the full impact of an enemy's change in operations with new equipment did not have an immediate impact at maximum effectiveness. If A/S forces stumbled to find solutions (and the British generally did better than that), the enemy took time to fully develop their new offensive techniques, which gave the British a breathing space to put countermeasures in place. To some extent, looking back on the problem, it depends on whether Vice Admiral J.M. Mansfield, Flag Officer, Submarines, was right in spring 1947 that: 'We stand...on the threshold of a complete revolution in submarine design and technique, and consequently in all types of anti-submarine measures.'[656] The alternative view of an experienced anti-submarine practitioner, Captain E.A. Gibbs, RN, Captain (D), Fourth Escort Flotilla, was that: 'Generally speaking the fast Submarine is not so much a new problem as a serious development of the old problem.'[657] The way in which tactical doctrine was developed in the Royal Navy over the period 1944-49 suggests that it was

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[656] 'HM Submarine *U-1407* – Trials,' 23 May 1947, RNSM A1977/043.
[657] 'Exercises with USS *Trumpetfish*,' Box 96, RG 313, NARA2.

Gibbs view which prevailed. Pragmatically, until new equipment became available, the Royal Navy could hardly choose another course.

The "Defensive" and "Offensive"

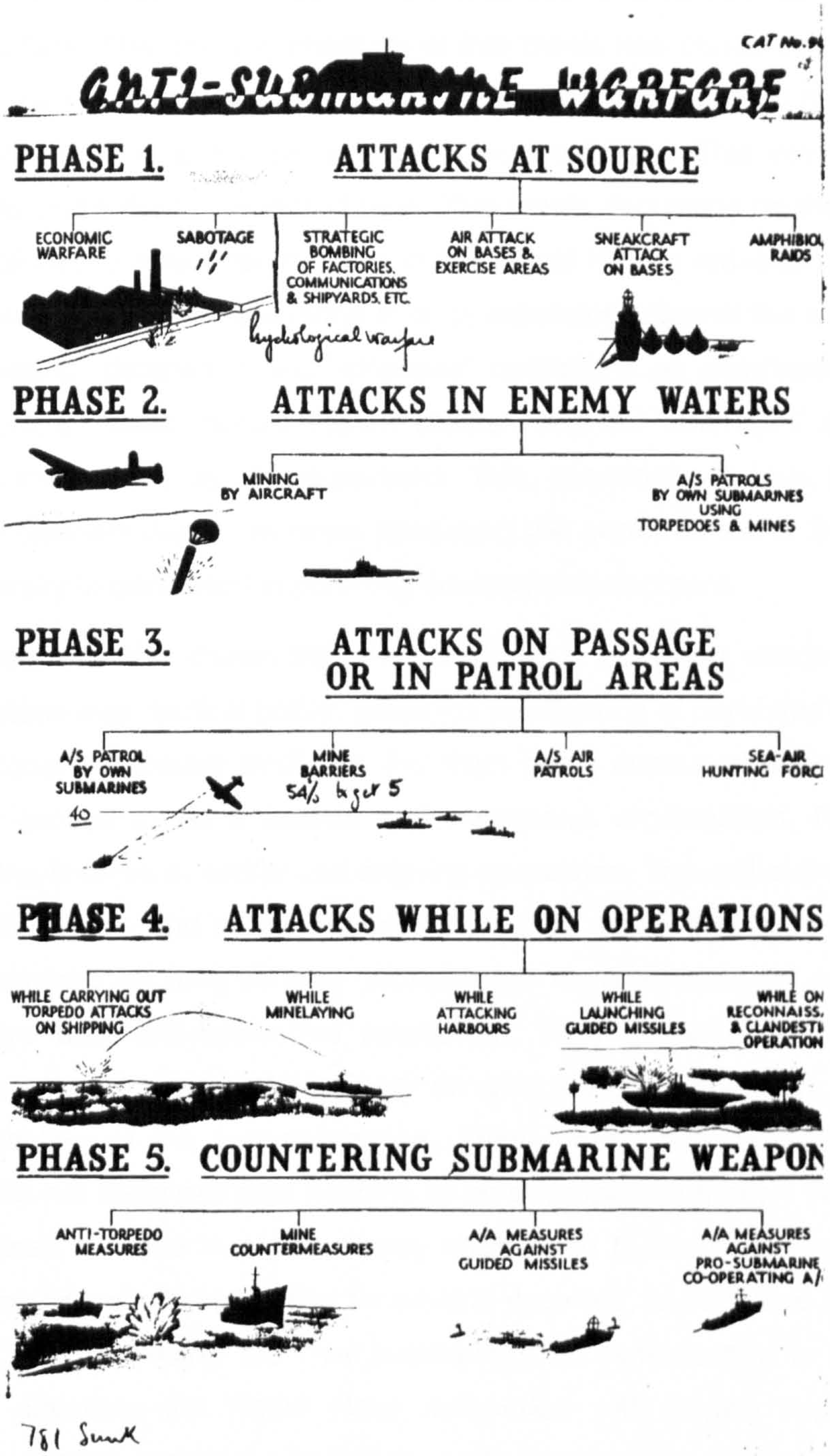
Many historians have followed the line that the primary goal of A/S warfare can best be articulated in the mantra of the "safe and timely arrival" of trade and that the best means of achieving this is to impose convoy. Furthermore, the convoy "defensive" escorts are best placed to destroy attacking submarines, whilst the alternative use of these A/S forces on "offensive" operations is inefficient. Thus convoy, by this logic, is transformed into an "offensive" measure. There is, of course, some measure of legitimacy in this view, but it is a caricature and will not do. For a start, it confuses the issues and, secondly, it is not how A/S warfare was seen by those who really understood it in 1944-49 (or even 1917-49). A/S practitioners realized that the "safe and timely arrival" of convoys was only part of the equation. If, at the same time A/S forces were not able to destroy sufficient numbers of submarines, their numbers would increase and (perhaps more crucially) the expertise and morale of their crews would improve. It was not necessary to sink more submarines than the enemy could build (a mistaken calculus adopted by the Germans as the principal aim of their anti-shipping campaign). It was only necessary to sink enough submarines to "keep their tails down", though it was not possible then, or now, to exactly quantify this number. As A/S specialists (and others) realized the fundamental difficulties associated with A/S warfare, meant that destroying submarines was an inherently inexact and inefficient business. The need, therefore, was to capitalize on every opportunity to attack the enemy. The question was how best was this to be done?

Theoretically, engaging submarines in the vicinity of a convoy put A/S forces at an advantage by concentrating escorts around the submarine's prey. The Germans had attempted to overturn this logic by massing a counter-concentration through their U-boat pack-tactic system. However, against a co-ordinated and aggressive defence even these enemy tactics failed. It was only when the enemy came up against an escort that was weak in numbers, capability and training, that they scored substantial success. This was, to simplify the complex argument of this thesis, because the convoy system created a number of tactical advantages for A/S forces. Firstly, as had just been noted, a convoy's escort formed a concentration of A/S forces. But the imposition of convoy, by congregating the ships into a small area, also effectively left wide expanses of the ocean bare of targets. This presented the submarine with two problems: locating the convoys, which drove the submarines to disperse to search, and then making them move (at relatively high speed) to close the convoy in order to attack, or to overtake the convoy so as to attack repeatedly. Submarines moving at speed are no longer stealthy, and present A/S forces with opportunities to locate and attack them. Up to 1944 this weakness of the U-boat was ruthlessly exploited by A/S forces in direct and distant support of convoys. These operations were augmented by (albeit often inefficient) operations over U-boat transit routes and attacks at source by submarines, direct aircraft attack and mining. Overall, about half the U-boats sunk were by the, so called "defensive" forces, and the other half by "offensive" operations.

The combination of "defensive" and "offensive" A/S operations was a well developed doctrine that had originated in the First World War and had survived unabated during the interwar years. The Royal Navy entered the Second World War fully confident that convoy provided the basic building-block of their A/S strategy. This had to be combined with aggressive action close to the convoys, and wider offensive operations designed to sink U-boats and, at least, to harass their every moment at sea and (ideally) in harbour. Force levels relative to the magnitude of the expanding convoy system and the growing power of the U-boats (magnified after the Fall of France) meant that a balanced "defensive" and "offensive" strategy had to be held in abeyance for a time, for simply finding sufficient resources for the direct defence of convoys stretched Allied resources to the limit. At moments of extreme peril this defence was largely passive. But as A/S forces grew in numbers and capability, the Royal Navy soon resurrected its long-held doctrine as "defensive" escorts became more active and aggressive. Sea and air support groups were assigned to threatened convoys, where they took the offensive, for they had the time to hunt U-boats to destruction. Gradually, too, the means of attack-at-source became more sophisticated with improved bombing techniques. Thus when the enemy abandoned the conventional submersible mode of operation and reverted to submerged patrols with schnorkel-fitted U-boats, the fundamental doctrine for dealing with them was already in use. This doctrine was expanded as the basis for countering the incipient threat of the fast U-boats at the end of the Second World War. The "offensive" and "defensive" were not entirely equal strategic or tactical partners, for if the "offensive" was to be successful, it had to rest on a sound "defensive" posture. It could not exist alone, whereas, the "defensive" could at least for a time. The fast submarine formed the benchmark of the post-war threat, against which the Royal Navy took forward the now well-established A/S warfare doctrine based on the holistic, symbiotic relationship between the "defence" and "offence" {*Plate 25*}.

Plate 25: Elements of Anti-Submarine Warfare

('The Development of A/S Warfare,' Instructional Tactical Lecture, H.M.S. Vernon, 10 June 1948, Adams Papers.)



Synthesis

There has been a widespread misunderstanding of application of anti-submarine doctrine by the Royal Navy from the First World War to the end of the Second World War. This has been caused by a failure to encompass adequate swathes of the primary record, and a lack of comprehension of the technical and tactical difficulties of anti-submarine warfare. The opening chapters of this thesis has corrected many of these errors and, in the remaining chapters has extended the research from the mid-years of the Second World War to the beginning of the Cold War. This era has not been covered before in the depth presented here. This thesis, focussing on the period 1944-49, has established a new interpretation of the Royal Navy's anti-submarine doctrine against the threat of the fast submarine and, by extension, against the wartime U-boat. Instead of treating "defensive" and "offensive" operations as alternative options, the Royal Navy took a holistic approach to the problem and the "defensive" and "offensive" were seen as interrelated, symbiotic partners. This, seemingly obvious, point provides a significantly different departure when assessing the performance of the Royal Navy (and the Admiralty in particular) in pursuing doctrinal development.

The thesis has also shown that the Admiralty, in particular, made accurate and sensible decisions over tactical policy, given the intelligence at hand and the limitations of the operational equipment available. Far from being conservative and ponderous, the Admiralty proved to be a flexible and responsive organisation. Furthermore, it learned from the lessons of earlier and ongoing operations. The anti-submarine division in the Admiralty by the end of the Second World War and in the immediate post-war years, was manned by long-service, professional naval officers, of whom the key personnel were also anti-submarine specialists. They brought their inter-war and wartime experience and knowledge to bear on what was, in many ways, the new anti-submarine problem of the fast submarine. These men were intelligent, pragmatic experts who did not allow practical doctrine to be swamped by theory. They also set in place the revised doctrine in a remarkably short span between 1946-48 – and one which was to remain a robust solution for several decades. At the same time, whatever the intrinsic case for seeing the new submarines as representing a "revolutionary" technological advance, the Royal Navy responded with largely tactical solutions designed to optimise existing equipment while simultaneously looking forward to improved technical solutions. It was realised that this new equipment would not be available for a considerable time and, even when operational, would not alter the fundamental combined "defensive" and "offensive" tactical posture. This presents an image of the Admiralty and of the Royal Navy at variance with much popular myth.

Appendices

The following Appendices are all direct transcriptions of original documents:

1. 'The Historical Section's View of the "Offensive" and "Defensive", 1955'
2. 'Anti-Submarine Training, 1939'
3. 'Tactics in the Battle of the Atlantic, December 1943 and January 1945'
4. 'Some Statistics of Anti-U-Boat Operations, 1943 and 1945'
5. 'Director of Torpedo, Anti-Submarine and Mine Warfare Division, 1945'
6. 'Assumed Performance of U-boats, 1946' and 'Notes on Walter Turbine or Closed Cycle Engines for Submerged Propulsion'
7. 'The German View of the Employment of the Type XXI U-Boat, 1944'
8. 'Walter Submarine Tactics, 1946'
9. 'Submarine Nomenclature, 1947'

Appendix 1

The Historical Section's View of the "Offensive" and "Defensive", 1955 [658]

Historical Section,
Admiralty,

15 October 1955

A "New Look" at
"Offence" and "Defence"
The Anti-U-boat Campaign
1939-1945
A Brief Statement of Facts

In a speech on 14 December 1954, on the role of the Royal Navy in war, widely reported in the press, the First Lord said, "I can at least, I hope, give some answers to those who profess to think that the inventions of today have relegated Navies to the defensive role of which the convoy system was the expression in the last two wars".

2. This view, that the convoy system is the embodiment of the defensive, is not substantiated by the facts of war ascertained by rigorous historical research. On the contrary, the facts show convoy to be the embodiment of the offensive.

3. In this scientific age methods of historical research for he naval staff are scientific. By the systematic collation of scrupulously verified facts and figures historical research is able to present statistical data for critical analysis and evaluation. By these methods of historical research it is possible, for instance, to determine with a high degree of certainty the relative efficacy of various measures taken to destroy or neutralise enemy forces and to preserve and employ our shipping most effectively. Thus through historical research the facts relating to the defeat of the enemy at sea in the last two wars reveal that, of all the measures we adopted, the convoy system alone provided the means for waging unremitting and highly remunerative offensive action: that, like any sound system of offence, the convoy system consistently provided the means for effectually countering all enemy counter-attacks: and, moreover, that of all the methods we adopted this advantage was a feature of the convoy system alone.

In short, historical research refutes the contention that the convoy system is "the embodiment of the defensive" and confirms the opinion expressed by Admiral Simms, USN, in 1917, that "convoy is a purely offensive measures."

4. In the Second World War U-boats sank 69% of all Allied shipping destroyed by the enemy. They achieved 80% of these sinkings in the Atlantic – Home Waters theatre. In order to substantiate the contentions in paragraph 2 above will, therefore, suffice to confine the facts to the salient ones relating to the U-boat anti-shipping and the Allied anti-submarine operations in that theatre.

5. In May 1943 the U-boats were decisively defeated at sea. They did not recover from that defeat. On no occasion after May 1943 did they inflict significant losses upon our shipping in convoy (Atlantic convoy losses amounted to twelve ships in the last two years of the war) although they continued to attack convoys and, as a consequence, suffered themselves very heavy losses.

6. Up to May 1943 we had used five principal means of attacking U-boats. Four of these were invariably referred to as "offensive". These four were intended to protect from attack primarily ships sailing independently. The protection was to be

[658] 'A "New Look" at "Offence" and "Defence",' NHB. [emphasis supplied]

afforded solely by the destruction of U-boats not directly threatening ships but which, if not destroyed, might at some future date encounter and sink defenceless ships.

7. The four "offensive" means were as follows:

(1) "Offensive" hunting patrols of surface and aircraft.

(2) "Offensive" patrols of aircraft in U-boat transit areas north of Scotland and in the Bay of Biscay.

(3) "Offensive" mining of U-boat bases and of U-boat training and trials areas, chiefly by aircraft.

(4) "Offensive" bombing of U-boat bases, building yards and assembly plants.

8. The object of these operations as typically defined as "the protection of our sea-lines of communication by offensive action". But, as stated above, it was in fact, to attempt to protect ships solely by attempting to destroy U-boats not directly threatening ships. These operations necessarily involved the dispersal of our A/S forces in attempts to seek out and attack U-boats in positions dictated by the enemy – the U-boat non-operational areas, and powerfully defended "sources". Furthermore these operations were necessarily unco-ordinated with the multitudinous movements of the defenceless independent ships at sea which they were intended to protect. As a consequence failure to destroy U-boats left the U-boats free to select where and when they would sink defenceless ships. In short, these inherently unsystematic and defensive operations endowed the U-boats with the initiative, rendering our ships vulnerable to attack and our A/S forces powerless to intervene when and where ships <u>were</u> attacked.

9. The results of the four "offensive" operations up to the defeat of the U-boats in May 1943 are revealing.

(1) U-boats destroyed by hunting patrols of surface and aircraft ... ... 21 or 9.4%

(2) U-boats destroyed by "offensive" patrols of aircraft in U-boat transit areas ... ... 24 or 10.6%

(3) U-boats destroyed by "offensive" mining ... ... 6 or 3%

(4) U-boats destroyed by "offensive" bombing of bases, etc. ... ... Nil.

<u>Total of U-boats destroyed by "offensive" methods</u> of all U-boats destroyed in this period ... ... 51 or 23%

<u>The number of ships sunk by U-boats while depending on these means for their protection</u>:

Sailing independently 1,363

Stragglers from convoys... ... ... <u>208</u>

Total ... ... 1,571 ships or 72%

10. <u>These lost ships amounted to 72% of the 2,191 ships sunk by U-boats in the Atlantic – Home Waters theatre in this period</u>. Their loss rate, that is, the number of ships sunk our of the number sailed, ranged between 3% and 25% according to their speed category; loss rates far beyond our building replacement rate.

11. The fifth means adopted of attacking U-boats – invariably referred to in Allied circles as "purely defensive" – was convoy. This system can be defined – but never is – as, the system of concentrating A/S forces into attack groups and sailing them with groups of merchant ships in accordance with pre-planned movements. Unlike the four "offensive" operation convoy operations are systematic. They are also aggressive. Unlike the forces employed for the "offensive" measures the convoy attack forces are concentrated at pre-selected times and at pre-selected positions

in accordance with the movements of our grouped ships, and are disposed so as to discharge concurrently two aggressive activities – to sink U-boats and to save ships under threat of attack. In fact the convoy attack forces dictate to the U-boats the time and place and tactical conditions of their attacks, for failure to attack convoys denies U-boats the opportunity of achieving their object, to sink ships. Seen from this point of view, which is the enemy's, the convoy system endows our A/S forces with the initiative in defence and in attack. It is essentially a scientific system of aggressive A/S operations.

12. This statement is substantiated by the results of convoy up to June 1943. These were:

(1) U-boats destroyed by convoy escort and support forces

... ... 150 or 65% of all destroyed

{fn. 14 U-boats (6%) were also lost "cause unknown" and 14 more (6%) destroyed by various other means}

(2) Number of ships sunk in convoy by U-boat while under escort of surface forces 604

Number of ships sunk in convoy by U-boat while under combined surface and air escort 16

Total convoy losses ... ... 620 or 28%

13. These lost ships amounted to 28% of all ships sunk by U-boats in the theatre, the loss rage being under 1%. (0.9% of the 69,500 ships sailed in ocean convoy, discounting the 128,000 ships convoyed in U Coastal convoys without loss). A loss rate well within the UK building replacement capacity.

14. Thus, "offensive" means cost us 72% of our shipping losses but inflicting only 23% of the enemy's losses.

In contrast convoy, the so-called "purely defensive" system, while involving only 28% of our shipping losses inflicted 65% of the enemy's losses.

15. This seeming paradox, that "defence" is the best means of attack as well as of defence and that "offensive" is the worst means of both, arises from the dogma – which is not based upon ascertained facts – that convoy is "a purely defensive measure". It is, indeed, a matter of mistaken identities. The error has arisen from two mutually contributory causes; the late nineteenth and twentieth century habit of discussing warfare in abstract and circumlocutory terms and failure to define the object of maritime forces with precision.

16. Thus the object of the enemy is currently defined as "to threaten our sea-lines of communications" or "our sea-communications", and the object of our maritime forces is defined as "to protect our sea lines of communication", or "sea-communications". This loose and abstract phraseology immediately conjectures up before the mind's eye vast stretches of sea in which an enemy may be lurking ready to strike at any time and in a diversity of places of his choosing. This is fantasy. The objects so defined are, in fact neither the enemy's nor our own; nor does the initiative lie with the enemy. Both objects can be stated quite simply and in concrete terms. The enemy's object in war is to stop us using ships – to sink our ships. This was the U-boat's object – to sink ships. Our object in war is to ensure the sage regular and frequent passage of our ships across the seas – in a phrase, to use our ships as we wish despite enemy opposition. The object of our A/S forces was to prevent the U-boats from sinking our ships.

17. These simply expressed and precisely defined objects deal with actualities, ships; the others, despite their high-sounding phraseology do not deal with realities. They deal with abstractions. Unlike them the simple and concrete definitions show clearly that it is we who hold the initiative for they reveal that the submarines could achieve their object in one way only, by sinking ships; that we, in contrast, could attain our object in three ways; by sinking submarines, by

frustrating submarines attacking ships, and by avoiding submarines. That, in fact, it was we who could choose where and when and in what strength our forces should operate because we could and can control the movements of the ships the enemy is seeking to sink. In fact, so long as we co-operate the dispositions and operations of our anti-submarine forces with the movements of our ships we hold the initiative.

18. Convoy enables us to do just this thing. It gives us the initiative in anti-submarine operations and it gives us the advantage of time and place. And this advantage, when related to the object, to prevent submarines from sinking ships, is, as Drake expressed it "half a victory, which being lost is irrecoverable". That aphorism in itself goes far toward explaining both the success of convoy as a means of saving ships and of sinking submarines and the failure of other "offensive" means to save ships and to inflict significant losses upon the submarines. The means called "offensive" forfeited in attack the advantages of time and place. The forces used were neither able to save ships directly threatened by U-boats, nor to sink submarines preoccupied with attempting to sink ships, advantages inherent in the convoy system of warfare.

19. But convoy has other inherent advantages. It is a fundamentally aggressive, scientific system. It is <u>scientific</u> because it deals with ascertained facts – ships, numbers of ships, and their intended movements. It is <u>systematic</u> because it embodies the planned movement of grouped merchant ships made in accordance with their numbers, steaming abilities and destinations, the availability of A/S craft and the anticipated numbers of enemy submarines.

It is <u>aggressive</u> for it dictates the movements of the U-boats because, if they are not to remain ineffectual the U-boats must endeavour to find and attempt to attack convoys with A/S forces ready and seeking to destroy them. The convoy system thus enables us to plan, to execute and to sustain aggressive anti-submarine operations; for the A/S craft accompanying the ships in every convoy are task forces over "disposed to attack" the enemy bold enough to risk the inevitable attack. It is the embodiment of the offensive spirit, of the <u>scientifically</u> calculated risk, but leaves very little to chance. Had this been more widely known – and it began to be appreciated in 1943 – some tens of the hundreds of bombers thrown away in the abortive offensive operations designed to destroy U-boats at source would no doubt have been made available for the lucrative convoy operations from which they were withheld on the grounds that convoy was purely defensive.

20. To conclude, on the enemy's own admission and as demonstrated by scientifically collated facts the convoy system twice decisively defeated the enemy. To inculcate into Statesmen, the Nation and the Services that the one successful inherently offensive, scientific and systematic method of warfare is defensive is to invite defeat. Actions are prompted by beliefs and desires. If the belief is wrong the action taken to realise the desire will be wrong. On this, History of war is adamant.

F. Barley
D.W. Waters

Appendix 2

Submarine Location: Notes in Reply to First Sea Lord's Enquiry, October 1929

The following are extracts from notes which were used to brief the First Sea Lord:

Note by A.B. Woods, Admiralty Research Laboratory, 9 November 1929 [659]

Introduction

A very large number of methods gave been proposed from time to time to detect and locate a submerged submarine. These methods may be classified broadly as follows:–

(1) Electrical

(2) Magnetic

(3) Electromagnetic – Induction (AC etc.)

– Radiation – visible

– infra-red

– W/T

(4) Mechanical (acoustic) – regarding the S/M as a source of sound

– Echo methods – High frequency sound (Asdics)

– Impulse

All these methods make use of some physical characteristics of the submarine, regarding the latter as a hollow metal body immersed in an extended electrically conducing fluid medium.

To deal with the above methods adequately would involve and extremely lengthy report. It may be stated, however, that in the light of our present knowledge methods (1), (2) and (3) can only be applied to submarine detection at relatively short ranges (of the order of a few hundred feet). This limitation of range is due to the fact that sea water is a conducting medium and all electrical and electro-magnetic effects (except of extremely low frequency, (1 or 2 pps.) are rapidly absorbed, whilst direct magnetic effects involve the inverse cube law of distance.

This leaves the mechanical (acoustic) method as the only long range method at our disposal. Here we may, under some circumstances, regard the submarine as a source of mechanical vibration (sound) which is transmitted through the sea. This vibration may be detected is transmitted through the sea. This vibration may be detected by means of numerous forms of hydrophone receivers. Apart from the "Asdic" (used as a hydrophone)none of these receivers can be used for submarine detection when the hunting ship is in motion at moderate speeds (above 10 knots). Again the submarine may be cruising at its "silent speed" (4 or 5 knots or so) or may be at rest on the sea bed. In such cases it emits little or no sound and all forms of hydrophone are useless.

Under such conditions the only method which has hitherto given reasonable promise of success is the Echo Method which makes use of the reflection of a high frequency sound beam from the submarine (whether at rest or in motion). We shall therefore now consider the limitations and prospects of improvement in this method.

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[659] 'Report on Methods of Submarine Location (Draft notes for reply to 1st Sea Lord enquiry dated October 1929),' [A.B. Woods, Admiralty Research Laboratory], 9 November 1929, ADM 218/273.

The Echo or "Asdic" Method. Limitations.

Details of this method are given in HMS *Osprey*'s report. A quartz oscillator (about 15" diameter) emits a narrow primary beam surrounded by a succession of secondary beams of diminishing intensity. This complex beam is reflected from the surface and bottom of the sea, form waves, and form strata of different density, salinity and temperature containing varying quantities of air in suspension. A distant submarine contributes a small reflection which is superimposed on this multitude of undesirable reflections (viz. reverberations). It is the object of the Asdic operator to discriminate between the feeble submarine echo and these reverberations. A further confusion arises, when wrecks, rocks or isolated masses of air bubbles give echoes resembling that from a submarine. The distinction between the real and false echo is often very subtle and requires a skilled operator to detect.

In addition to reverberation and false echoes, a further difficulty arises due to the motion of the Asdic transmitter (or rather the dome which encloses it) through the sea. At speeds above 12 knots the "speed noise" as it is called may become very serious and may limit considerably the range of echo detection. Again, masses of air bubbles, carried down beneath the ship from the bows often suppress the transmission and result in what is called "quenching"; no echo, or reverberation, can be expected under these conditions.

With the existing Asdic system [in 1929], therefore, there are two serious factors tending to reduce the range and certainty of detection of the echo, viz.:–

(1) Reverberation, and

(2) Dome noise (or "speed" noise) and "quenching".

The possibility of improvement of the echo method therefore lies primarily in the reduction of reverberation and speed noise relative to the echo. ...

Note by B.S. Smith, HMS *Osprey*, 14 August 1929 [660]

With reference to your Reference sheet of 8 July [1929] enclosing a not on "A Method for Obtaining a Rotatable Supersonic Beam from a Fixed Transmitter", I am fully in agreement with Dr. Drysdale that it is most desirable that new work in connection with Asdic transmitters should be concentrated on methods which give some promise of overcoming the limitations of the present oscillators rather than dealing with devices, which at their best, can only equal the performance of the existing gear.

It may be helpful in getting a clear idea of the present position to review what I consider to be the real limitations in the performance of the existing apparatus –

(a) Range of Detection of Large Targets. The echoes from a "large target" e.g. a beam-on submarine are stronger than the reverberations at all ranges. The minimum receivable strength of echo is fixed by the disturbances that are present at the receiver. At slow speed the final limit is set by sea and ship's noises which vary from day to day, while at high speed a much greater limitation is imposed by "speed noises", which are due to the disturbances at the dome and on the hull.

The increase in range obtainable by increased power is fixed by the transmission factor of the water. At a frequency of 20,000 cycles/second under average conditions a four-fold increase in power gives an increase of between 200 and 800 yards in the range, while at lower frequencies, e.g. 10,000 the transmission factors are more favourable. A 15" asdic oscillator at 20,000

[660] B.S. Smith, HMS *Osprey*, to Director, Scientific Research & Experimental Department, Admiralty, 14 August 1929, ADM 218/273.

cycles with an output of 50 watts may be expected to give a range of the order of 6,000 yards on a beam-on submarine when the transmission factor is about 500 yards. These ranges may be doubled if the transmission factor is specially favourable and the target is very large, e.g. Nab Tower. There is no reason to doubt that the average range on "large targets" can be increased very materially by increased power, but a very large increase in output is necessary to double the average range. For example, to increase the range on a beam-on submarine under the conditions quoted above, the poser of the oscillator would have to be increased $(4,000)^2$ times!

(b) Range on Small Targets. With an end-on submarine the echo strengths at moderate ranges are almost equal to the strength of the reverberations.

With the submarine stopped the echo may be rendered inaudible by the nose produced by the reverberations, but when the submarine is moving, the slight difference in pitch between the echo and reverberation makes detection possible. Under these conditions increases in power do not improve the audibility if the echo as both the reverberation and the echo are increased in intensity.

The ratio of echo to reverberation strength is the most important factor in the detection of a "small target", and measurements of the arc over which such echoes are detectable show that the ratio improves very slowly a the range is reduced. For example, if the maximum range at which reverberations are heard is, say, 4,000 yards, the echo may only be detected over a an arc of 1°, while at 2,500 yards the arc may be increased to say 5°. The effect of training the oscillator 2½° off the direction of the target is to reduce the echo strength 6% while the strength of the reverberations is unchanged. This small reduction is enough to render the echo inaudible even at moderate ranges.

In all existing oscillators the energy concentrated n a cone of 2x2½° along the axis is only a very small fraction of the total energy. At moderate ranges only this small fraction assists in the detection of the small target while the bulk of the energy, emitted at greater angles increases the strength of the reverberations which tend to mask the echoes.

If a greater proportion of the total energy could be concentrated in a small cone, it is reasonable to assume that the audibility of the echo would be improved. Such an improvement would undoubtedly add greatly to the certainty of detection of a small target by asdics.

(c) Non-Submarine Echoes. Although the elimination of all types of non-submarine echoes cannot by regarded as possible, many of the false reports which are made during sweeping exercises are possible to eliminate with improved apparatus. For example, in deep water echoes from ranges approximating to the depth are frequently reported and there can be no doubt that they are caused by energy, outside the main beam of the oscillator, being reflected from the bottom. It is also a fact that echoes are obtained from secondary emission under certain conditions. Although a fairly simple procedure enables an operator to class such echoes as "non-submarine" valuable time is lost in carrying out the necessary tests, and it would be a great advantage in practice if these non-submarine echoes were eliminated by suppressing secondary emission.

(d) Detection of Submarine by Sweeping. When searching for a submarine, it is necessary to "sweep" s wide a lane as possible at speeds up to 20 knots.

At slow speeds the width of the lane swept by each ship is nearly twice the maximum range at which the submarine can be detected with certainty over an arc of 5° when approaching bows-on. This range (termed the working range) is very much less than the maximum range at which a similar target may be detected over an arc of 1 or 2 degrees.

At 20 knots the time taken to sweep in steps of 5° reduces the width of the lane that is effectively covered by the sweep, and in practice the width of the lane may be less than the working range.

Another factor which reduces the width of the lane is the delays which are caused [by] substantiating echoes to test whether they are from a submarine or not.

In all these cases the area swept would be materially increased if it were possible to increase the arc of detection at the maximum range. It is reasonable to assume that such an increase would be attained if a larger proportion of the output of the oscillator were concentrated in the main beam.

To sum up these considerations:–

(1) While increase in output of the transmitters are not to be despised there is little prospect of increasing range materially by this means.

(2) When using asdics as a detector, the area that can be swept in a give time, rather than the maximum range of detection, is the true measure of its performance.

(3) A material increase in the are swept may be expected if the arc of detection can be increased by improving the beam characteristics.

(4) Improvements in the beam characteristics may be expected to render detection of the bows-on submarine more certain and also assist in the elimination of non-submarine echoes.

As far as I can see at present the ideal beam for detection would be one having constant intensity over a small angle, say 10°, with the minimum energy over the remaining 350°.

I have no data at present with regard to the ideal characteristics in the vertical plane, but experiments we are making with strip oscillators may throw some light on this

For locating the submarine, it would be advantageous to be able to concentrate the beam over a smaller angle.

I think it is generally agreed that the limitation of the diameter of the oscillator to 15", or even 24", leaves little scope for making radical improvements in the characteristics and concentration of the beam and that oscillators of very large diameter are impracticable. ...

Anti-Submarine Training, 1939 [661]

The following note was provided by Admiralty D. Pound, First Sea Lord, to Admiral A.B. Cunningham, Commander-in-Chief, Mediterranean in June 1939:

A/S is unlike any other form of attack. It is an attempt to sink an invisible enemy by a sense which is not in every day use. A/S efficiency depends on the appreciation of the quality of a sound. It is very much harder to distinguish between two notes of the same pitch played by different instruments, than to appreciate that a note is being struck.

In the case of Gunnery of Torpedo it is a comparatively simple job to teach officers and men on watch to commence the attack, and the full ship's company can probably be closed up before the full attack develops even with air attacks, but with submarines the range at which information is obtained is so close and the differentiation between non-sub echoes and the real thing so near that time will not

[661] 'Anti-Submarine Training,' ADM 205/3.

always permit for anyone but the Officer of the Watch and the operators on watch to take part in the attack.

It is obvious that the Commanding Officer and A/S Control Officer cannot permanently be on the bridge throughout the 24 hours of a perhaps ten to fourteen days' patrol, and therefore all officers must be trained to control and complete confidence must be gained in the operators. For this reason all ratings who are qualified must be kept in constant training so that depth-charges are not wasted on non-sub echoes or in carrying out bad attacks.

2. The Asdic operator has to keep in mind what a submarine echo may sound like under all conditions and so distinguish it from other almost exactly similar sounds. Once he can do this with certainty he has overcome ninety per cent of the difficult. Once he has distinguished his target, strict attention to his procedure drill will enable him to keep in contact provided the ship is manoeuvred correctly. The efficiency of the ship depends therefore firstly on the training of the operator and secondly on the training of the officer conducting the attack.

3. Four points require particular attention in the training of the operators and the officers.

Firstly. The operators must have frequent practice at sea, once they have achieved the standard of being able to distinguish between echoes. Without this practice they very soon forget the sound of a submarine echo, as a sound is very much more difficult to memorise than something that can be seen or felt. It is emphasised that the operator must be able to distinguish echoes under ALL circumstances and so must operate in bad conditions as well as good.

Secondly. As concentration is such a large factor in assisting the operator to distinguish the target, disturbing noises should be reduced to a minimum and attention paid to the operator's comfort. The control officer should reduce his remarks to a minimum and make every effort to get them heard first time.

Thirdly. The state of efficiency of the material must be most strictly maintained. Minor interference due to low insulation or dirt in such placed as the connector, the S/R key or the control training unit causes extra noise and must be removed.

Fourthly. Although with the recorder and the plot the officers require less practice in carrying out an attack, they should be practiced at the same time as the ratings. Training should not be confined only to A/S Control Officers, but all watchkeeping officers should be included. The new attack teacher in HMS *Woolwich* is of great value to officers, but owing to the unrealistic echo is not so useful to operators.

4. Every moment of a practice should be utilised. If a tactical hunt has been decided on and conditions are bad, it should be turned into a training hunt. People should not be intimidated into fear of not producing enough tactical hunts per quarter – efficiency of ratings is far more important than paper returns.

5. Two nucleus crew destroyers at Home Ports and Bases abroad with attendant submarine, in which A/S personnel from ships refitting or otherwise engaged could be sent to sea for practice would be invaluable in helping to keep continuity of training.

6. Attached to this paper is a proposed programme for carrying out training, The results of any technical practices should be analysed without delay and exhibited prominently.

New Commanding Officers, new A/S Control Officers and new operators joining a ship should all be practiced in non tactical exercises until confidence has been established. These should also take place when a month or so had elapsed since the last practice.

This programme should be used as a guide only. Hard and fast rules cannot be made as the only guide is the efficiency of the operator. The Flotilla A/S officers and instructors should go to sea in each ship of the flotilla to watch the progress of all operator and so judge the standard achieved. This is of the utmost importance in deciding what exercises a ship requires to bring her up to standard. All operators, good or bad, should be given practice. If bad operators are concentrated on, the good ones will deteriorate.

Where few opportunities for practice occur it is considered that greater value could be obtained by increasing the number of phones which can be connected to the amplifier, in order to give more ratings the opportunity of hearing the echo.

7. The following remarks on Fleet Exercises are also forwarded:–

Certain peace restrictions have to be observed which unless properly considered are liable to give false conclusions to A/S vessels and submarines. In view of the necessity of exercising both arms, some exercises are produced which allow the submarine to be at periscope depth when attacking a screened fleet until they have fired a torpedo. This in effect gives the A/S personnel a wrong impression of how to counter-attack as they are not allowed to go within 1,200 yards of a periscope, and also gives the submarine officers a wrong impression of the action of a screen on obtaining contact.

Screens should be sufficiently far ahead to allow of investigation before the submarine is a menace {fn I do not consider that a submarine firing an outfit of six torpedoes at 8,000 yards is a menace. A destroyer flotilla with 72 torpedoes would endeavour to obtain closer range.} to the fleet (about 4,000 yards). Be allowed to drop back and continue attacking until the fleet is no longer endangered and then rejoin at once, as one cannot afford to deplete the screen for longer than necessary. In this connection unless spare destroyers are available, after the first counter-attack one destroyer only should fall back as it is essential to keep the screen as complete as possible. The length of time to rejoin a high speed fleet is considerable especially in bad weather.

If the number of screening vessels is insufficient, they should act as a close screen making as much use as possible of their A/S but not waiting to confirm. In this case a certain number of false reports must be expected and a full pattern not used unless periscope or other confirmation is obtained.

8. If it is desired to exercise submarines using their periscope to fire torpedoes, screen should take no action except to note the time and position of first contact and holding contact.

9. Unless an A/S officer is borne on the staff, the senior officer being screened should if possible consult the senior officer of screening force as the best screen to form with [the] forces available.

10. Whilst healthy rivalry between submarines and anti-submarines is of good value, loyal co-operation between the two services is essential to obtain the best training for personnel of both branches.

Anti-Submarine Training - Appendix

Instructional Programme for New Flotilla

(ASP's are described in CB 4000.)

Daily in Harbour

Procedure Drill. Care and Maintenance. Records.

This can be done in half-hour per day during clean guns.

Working up at Sea

First Week	Second Week	Third Week	Fourth Week
Lecture to explain procedure			
ASP6 Six hours per ship	ASP6 Four hours ASP7	ASP6 Four hours ASP7	ASP7 Two hours ASP9

	Two hours	Two hours	Two hours ASP11 Two hours

After working up at Sea

Weekly	Monthly
ASP7 Two hours ASP9 Two hours or ASP11 Four hours ATH One forenoon	ASP16 or ASP17 and fleet screening with counter-attacking if possible.

In many of these exercises additional practice can be obtained by carrying out ASP12 on the approach to the rendezvous.

Appendix 3

Tactics in the Battle of the Atlantic, December 1943 and January 1945

Hush Most Secret Cypher Message[662]

Battle of the Atlantic
Recent Changes in Enemy Tactics

[December 1943]

...following review is promulgated for the guidance of Senior Officers of Escort Groups.

2. Experience during the last few weeks has shown that U-boats are now rarely on the surface by day. This implies a very marked change of tactics which calls for a corresponding change in our counter-measures.

3. By remaining submerged by day the enemy reduces the risk of detection and counter-attack but at the same time denies himself the following advantages of his previous policy.

(a) Surface reconnaissance and immediate receipt of sighting reports by consorts.

(b) Subsequent shadowing and homing of consorts.

(c) The ability to trail a convoy and carry out a series of attacks extending over a number of days.

(d) The mobility which enables the more distant U-boats to intercept a reported convoy.

4. Such tactics have already greatly promoted the safe and timely arrival of the convoys, but they must inevitably give us fewer opportunities to destroy the enemy. It is my intention now to take full advantage of the enemy's weakened offensive by neglecting no opportunity to destroy him whenever contact is made.

5. To this end orders may be expected under certain circumstances for Support Groups, and even a proportion of the Close Escort, in the aftermath of a battle to leave the convoy and return to the battle area for mopping up.

6. I desire that Commanding Officers should henceforward use more care and deliberation in the execution of their attacks on U-boats which are not an immediate threat to the convoy. It has become increasingly clear that the old methods of depth-charge attack which, provide such ample warning of their approach, are not effective against a deep and highly manoeuvrable U-boat.

7. In the Hedgehog and in the Squid are combined the two attributes of precision and surprise which ensure its effectiveness in a deliberate attack. For a U-boat which is too deep for the Hedgehog, the "Creeping Attack", which has the same attributes, has recently proved on three occasions its deadly day accuracy.

8. It is my view that, when Escorts are hunting in pairs, the delivery of the standard depth-charge attacks on a deep submarine are no longer justified except for the purpose [of] driving it deeper for a "Creeping Attack".

TOO 142141A December 1943, CSO(M), C-in-C, WA

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[662] This extract was provided by Norman Goodwin, Archivist of the Castle Class Corvette Association, 8 August 2003, and is taken from the draft extract of F.N. Goodwin, *Castle Class Corvettes (Frigates): An Account of the Service of the Ships and their Ships' Companies* (Castle Class Corvette (Frigate) Association (forthcoming)), which drew on 'HMS *Helmsdale*: Report of Proceedings of B4 Escort Group of Convoys OS64 and KMS38, from 5-17 January 1944,' ADM 217/358.

Enemy Anti-Asdic Tactics [January 1945] [663]

(It is emphasised that the following information is the result of questioning of one officer only. It refers, of course, to existing U-boats; the Type XXI and Type XXIII would presumably rely for evasion on their high underwater speed and endurance. The tactics described here are sound and confirm generally our own views.)

Deep water

Standard recommended practice is to dive at once to about 650 ft (previous reports gave 560 ft). This operation takes about four minutes and, at least in the early stages, half-speed is used. A line of SBT targets should then be laid as nearly as possible at right angles to the approach course of the attacking vessel. SBT laying is normally commenced at about 525 ft and either three or four are ejected. Time required for re-loading is 20 to 30 seconds, but up to three pills can be fired at once if required. Normally, this Prisoner of War would reckon on laying either three or four SBTs in 100 seconds at a depth about 80 ft shallower than that in which he subsequently intended to operate.

At about 590 ft the motors are reduced to silent speed and the U-boat attempts to shelter behind the SBTs just laid. ("Silent" speed for a particular boat is ascertained during trials; it is usually about 90 revs., something under three knots.) As soon as the attacking vessel is heard to increase speed on the run in, it is usual to put the wheel hard over one way or the other, but not to increase to more than half-speed. Working the motors to increase rate of turn is not recommended on account of extra noise.

The Prisoner of War considers it preferable, at night or in low visibility, to remain on the surface or at periscope depth and fire a "Gnat" at any vessel which looks like coming in to attack. He suggested that the majority of seasoned U-boat captains would now adopt these tactics rather than dive deep. In good visibility, resulting in a greater range of sighting, he would probably dive.

Shallow Water

The general opinion is that SBT is comparatively useless in shallow water and may even lead to betrayal of the U-boat's whereabouts. In areas such as the Channel the standard practice is to seek the shallowest possible (sic) water and there to lie on the bottom. If possible the U-boat selects a depression in the sea-bed in otherwise shallow water. The experiences of Commanding Officers in shallow water are being collated by the enemy and though, as yet, no instructions or special charts have been produced, boats sailing for the Channel have, amongst their sailing orders, all possible information as to the exact positions where previous U-boats have laid undetected when hunted.

To bottom in, say, 160 ft of water takes about 4 minutes, on the average, to accomplish. The echo-sounder must be used repeatedly when bottoming. The Prisoner of War did not know the frequency of the echo-sounder used, but described it as the "Atlas Echolot" (sonic; 1½ or 3 Kc/s).

Great use is made of water-layering whenever possible; this is almost invariably detected by the depth-keeping behaviour of the boat. If sudden falls or rises occur, the Commanding Officer at once attempts to go a little deeper in the same area and to remain under the point where the layering has been observed.

663 'Enemy Anti-Asdic Tactics,' Section 5, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB, pp. 12-13.

Appendix 4

Some Statistics of Anti-U-Boat Operations, 1943 and 1945

Aircraft Depth-charge Attacks in 1943 [664]

	Number of DC attacks in 1943	Proportion of lethal attacks	Proportion of damaging attacks
January-March	143	8%	16%
April-June	237	10%	10%
July-September	80	27%	15%
October-November	40	28%	10%

Weapons used in Attacks on U-boat during Last Half of 1943 [665]

Weapon	Last half of 1943	
DC (Ship)	11	21%
Hedgehog	4	7½%
Ram	1	2%
RP	3	5½%
DC (Aircraft)	32	60%
A/S Bomb	2	4%
Total	53	100%

Inshore Campaign against U-Boat Operations, 1945 [666]

This analysis contains the following data on the inshore U-boat campaign from July 1944 to May 1945:

The phases were divided as follows:

Phase 1	July to mid September 1944
Phase 2	mid September to mid December 1944
Phase 3	mid December 1944 to mid February 1945
Phase 4	mid February to May 1945

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664 'Note on Depth Charge Attacks by Aircraft,' [L. Solomon], CAOR, 17 February 1944, CCAC, FWCT 2/4/5.
665 'Monthly Anti-Submarine Report, September 1944,' ADM 199/2061.
666 'Survey of A/U Operations...,' ADM 1/17653.

Phase	Torpedoings		U-boats Sunk				Ships torp. Per U-boat sunk
	Incidents (% avenged)	Ships Torpedoed	By Ships		By aircraft	Total	
			After torpedoing	Others			
I. 80 days	23 (13%)	26	3	8	1	12	2.2
II. 90 days	3 (0%)	3	0	2	1	3	1.0
III. 60 days	18 (17%)	23	3	1	1	5	4.6
IV. 80 days	31 (26%)	35	8	12	6	26	1.3
Total	75 (19%)	87	14	23	9	46	1.9

The duty of the escorts at the time of U-boat sinkings were:

Duty	Escorting or Supporting Convoy	Patrolling	Total
U-boats sunk after torpedoing ship	6	8	14
No ship torpedoed	5	18	23
Total	11	26	37

Appendix 5

Director of Torpedo, Anti-Submarine and Mine Warfare Division, 1945

Office Memorandum No. 394 is reproduced below:[667]

On 10 September 1945, a new Division of the Naval Staff was set up to deal with Torpedo, Anti-Submarine and Mine Warfare. It was formed by the amalgamation of DASW, the Torpedo Section of DTSD, and DDOD(M), and is to be known as the Torpedo, Anti-Submarine and Mine Warfare Division (short title TASW).

2. The following appointments have been made to the TASW Division:-

DTASW	Captain Lord Ashbourne, DSO, RN
Assistant Director (Torpedo)	Captain J. Hext Lewes, OBE, RN
Assistant Director (Anti-Submarine)	Captain P.W. Burnett, DSO, DSC, RN
Assistant Director (Mine Warfare)	Captain V.D'A. Donaldson, RN
Assistant Director	Captain F.M. Mason, RN

3. ...

4. A new series of registered papers will be instituted, which will be numbered in the TASW series.

5. Instructions will be promulgated in due course.

6. In consequence of the formation of the new Division, the Director of Tactical, Torpedo and Staff Duties Division will in future be known as the Director of Tactical and Staff Duties Division (his short title, DTSD, will remain unchanged).

7. DASW ceases to exist as a separate Staff Division.

Office Memorandum No. 147 is reproduced below:[668]

<u>Instructions for the Director of Torpedo, Anti-Submarine and Mine Warfare Division</u>

The Director of Torpedo, Anti-Submarine and Mine Warfare Division is responsible to the Board for the efficient performance of the duties of his Division. He works under the superintendence of the Assistant Chief of the Naval Staff (Weapons).

<u>Torpedo</u>

2. He is responsible for advising on:–

(a) the influence of torpedo development on strategy and tactics;

(b) torpedo aspects of planning an operations;

(c) tactical countermeasures against all forms of torpedo attack.

3. He is responsible for Staff Requirements for the following items:–

(a) torpedo armament of HM Ships generally;

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667 'Torpedo, Anti-Submarine and Mine Warfare Division – Institution,' H.V. Markham, Office Memorandum No. 394, CE.58514/45, 24 September 1945, ADM 1/17743.

668 'Instructions for the Director of Torpedo, Anti-Submarine and Mine Warfare Division,' Office Memorandum No. 147, CE.58776/45, 29 March 1946, ADM 1/17743.

(b) new torpedoes and their components (e.g. pistol, homing devices, etc.);

(c) torpedo discharge gear in ships, MTB's and S/M's;

(d) torpedo control gear in ships MTB's and S/M's;

(e) allocation of torpedo reserves, including the staff aspect of the periodical review of quantitative requirements of torpedoes;

(f) material countermeasures against all forms of torpedo attack, excluding A/T nets.

4. He is responsible for torpedo analysis of actions and practices, and promulgation of lessons learnt, and for the preparation of an annual summary of torpedoes fired in action and practice.

5. He is responsible for the staff aspect of diving.

6. He is responsible for Admiralty publications dealing with torpedo control policy, tactics, practices and exercises.

Anti-Submarine Warfare

7. He is responsible for advising on all matters affecting the conduct of anti-submarine operations, and in particular on:–

(a) policy for conduct of A/S operations;

(b) planning of A/S operations;

(c) A/S tactics in so far as they affect convoys, fleet protection, offensive operations, A/S weapons, underwater detecting devices and harbour defence;

(d) disposition of A/S vessels and aircraft;

(e) the application of A/S requirements to the development of air policy and tactics.

(f) air/sea co-operation in relation to A/S Warfare.

8. He is responsible for Staff Requirements of A/S vessels and A/S Staff Requirements HM Ships and (in consultation with D of LD) defended harbours generally and in particular for the Staff Requirements for:–

(a) A/S weapons and equipment of all descriptions;

(b) A/S control and detection gear including hydrophones and other underwater listening devices;

(c) A/S application of echo-sounding hear;

(d) subsidiary acoustic devices (e.g. SBT, sonobuoys, etc.);

(e) anti-asdic and anti-hydrophone equipment and devices;

(f) allocation of reserves of A/S weapons, including the Staff aspect of the periodical review of quantitative requirements for the production of ammunition for A/S weapons;

(g) underwater detecting systems used in Harbour Defence;

(h) equipment of Admiralty Cable Ships and boats designed for laying loops;

(i) equipment of shore and ship borne control stations for indicator loops and miniature loops.

9. He is responsible for analysis of A/S actions and practices and promulgation of lessons learnt, for instruction and training in A/S subjects, and for the co-ordination of sea-going A/S training of A/S vessels and aircraft.

10. He is responsible for Admiralty publications dealing with A/S warfare, history, policy and tactics.

11. He is responsible for framing policy in regard to Admiralty Cable Ships, their equipment and personnel.

Mine Warfare

(A) Mining

12. He is responsible for Staff Requirements for:–

(a) mines of all descriptions and their components;

(b) minelayers and minelaying equipment;

(c) demolition explosives and gear;

(d) reserves of mines, minelaying equipment and demolition stores, including the staff aspect of the periodical review of quantitative requirements for the production of mines and demolition stores;

(e) mine depôts and bases and mine issuing ships;

(f) controlled minefields (L), (O) and (A), (in consultation with D of LD);

(g) equipment of control stations and observation minefields.

13. He is responsible for minelaying policy, for the planning of minelaying operations, for the allocation of mines, and for records and analyses of all minelaying operations, and promulgating lessons learnt.

14. He is responsible for mining charts of British and Allied mines and for providing the Hydrographer with the relevant information for promulgation.

15. He is responsible for the preparation pf statistics and for Admiralty publications dealing with minelaying policy, tactics and history.

(B) Minesweeping

16. He is responsible for Staff Requirements for:–

(a) minesweepers and minesweeping gear of all descriptions, including mine location, paravanes and TSDS;

(b) anti-mining gear other than sweeps, e.g. DG gear;

(c) scale of production, reserves, and distribution of minesweeping gear of all descriptions, and also GD gear.

17. He is responsible for:–

(a) minesweeping, minewatching and aerial spotting policy;

(b) the analysis of operations and exercises;

(c) records and statistics of minesweeping;

(d) advice on minesweeping training at sea;

(e) advice on the disposition of M/S Vessels.

18. He is responsible for supplying information concerning details of searched channels and the positions of enemy minefields to the Hydrographer for promulgation.

19. He is responsible for the preparation of manuals on minesweeping, except for those already the responsibility of technical departments.

Personnel

20. He is required to advise on:–

(a) the policy in regard to the technical training and practical use of all weapons, devices and equipment connected with Torpedo, Anti-Submarine and Mine Warfare;

(b) questions concerning the application of approved principles of TAS training;

(c) syllabuses for all TAS courses.

21. He is responsible for:–

(a) framing the policy in regard to TAS and M/S training schools in the UK and overseas, wherever they are an RN commitment. He is responsible for maintaining a close liaison with these schools, and also with those in the Dominions and India, on all matters concerning instruction, instructional appliances, synthetic training devices, films, etc. – DUW, however, is responsible for instruction being sufficient to cover the correct preparation and maintenance of the weapons employed.

(b) Arranging TAS courses for foreign officers and ratings;

(c) The preparation and revision of the TAS Training Manual.

22. He is to maintain close touch with:–

(a) DUW on matters of training in so far as it affects the functioning of material.

(b) DUW on matters of complement and Quarter Bills for which DUW is responsible.

(c) DTSD on matters concerning the entry and technical training of officers and men to meet projected new requirements.

(d) HMS *Vernon*, HMS *Osprey* and HMS *Lochinvar* in the preparation of all syllabuses for courses.

23. In these duties, and all other matters affecting officers and ratings of the TAS Branch, he is to maintain a close liaison with Second Sea Lord's departments.

24. He is responsible for maintaining liaison with the Air Ministry, through the appropriate Air Divisions of the Naval Staff, on matters concerning the training of RAF personnel in TAS subjects.

Bases

25. He is responsible for advising the Divisions and Departments concerned on the broad requirements of bases intended for use of Minesweeping, Minelaying and Anti-Submarine forces.

Committees

26. He is a member of the following Committees:–

(1) Torpedo

(a) Torpedo control Committee.

(b) Aircraft Torpedo Requirements Committee.

(c) Aircraft Torpedo Allocation Committee.

(d) Gnat Panel (Counter-measures to Homing Torpedo).

(e) Torpedo Design Committee.

(f) Torpedo Tube Design Committee.

(g) Aircraft Torpedo Control Committee.

(2) Anti-Submarine

(a) A/S Warfare Committee (Secretary)

(b) Anti-U-Boat Warfare Committee.

(c) Training Devices Committee.

(d) Gnat Panel.

(3) Personnel

(a) DNT's Training Committee.

(b) Training Devices Committee.

Correspondence

27. He may sign correspondence with Dockyard and other Admiralty establishments at home and abroad, with individual officers of HM Navy or Civil Service on matters dealing exclusively with the duties of his Division, but all correspondence communication Board decisions, or concerning important questions of principle, or affecting other Departments, is to be in the name of the Board and is to be signed by the Secretary.

Appendix 6

Assumed Performance of U-boats, 1946 [669]

In 1946 the assumed performance of U-boats was:

Submarine	***Type VIIC***	***Type IXC***	***Type XXI***	***Type XXIII***
Tonnage (standard)	500 tons	740 tons	1600 tons	230 tons
Length	218 feet	252 feet	251½ feet	113½ feet
Beam	20 feet	22 feet	21½ feet	10 feet
Draught	15 feet	14½ feet	20½ feet	12 feet
Test Diving Depth	330 feet [1]	330 feet [1]	393 feet [2]	330 feet
Diesels Motors	2310 hp 750 hp	4400 hp 1000 hp	4000 hp 5000 hp	575 hp 580 hp
Speed: Surface Submerged	 17.9 knots 8 knots	 18.3 knots 7.3 knots	 15.6 knots 16 knots	 9.75 knots 12.5 knots[3]
Oil Fuel	113 tons	208 tons	250 tons	18 tons
Battery Capacity	9160 amp hrs	1130 amp hrs	30000 amp hrs	5400 amp hrs
Torpedoes (tubes)	14 (4 bow and 1 stern)	22 (4 bow, 2 stern)	20 (6 bow)	2 (2 bow)
Max Endurance: Surfaced Submerged	 9700 miles 130	 16300 miles 128	 15500 miles 365 at 5 knots 110 at 10 knots	 4300 miles 175 at 4 knots 43 at 10 knots
Complement	44	48	57	14
Guns	1-37 mm 2-twin 20 mm	1-37 mm 2-twin 20 mm	2-twin 30 mm	none

[1] The maximum diving depth was up to 2½ times deeper.
[2] British trials indicated that the hull would fail at about 800 feet.
[3] British trials achieved only 9.5 knots.

Submarine	**Type XXI**	***Type XXVI W***	***Type XVII B***	**Possible "True Submarine"**
Tonnage (standard)	1600 tons	730 tons	313 tons	730 tons
Length	251½ feet	184½ feet	136 feet	184½ feet
Beam	21½ feet	18 feet	11 feet	18 feet
Draught	20½ feet	19½ feet	14 feet	19½ feet
Test Diving Depth	393 feet	443 feet	330 feet	443 feet
Turbine Diesels Motors	- 4000 hp 5000 hp	7500 hp 575 hp 580 hp	2500 hp 210 hp 755 hp	7500 hp - -
Speed: Surface Submerged	 15.6 knots 16 knots	 11 knots 24 knots	 8.8 knots 20 knots	 24 knots
Oil Fuel	250 tons	65 tons	20 tons	30 tons
Ingolin	-	97	55	200
Battery Capacity	30000 amp hrs	11600 amp hrs	4940 amp hrs	none
Torpedoes (tubes)	20 (6 bow)	10 (4 bow, 6 lateral stern)	4 (2 bow)	10 (4 bow, 6 lateral stern)

[669] 'Performance of U-boats,' Appendix I and Appendix II to TASW.021/46, Revised, 4 May 1946, ADM 1/20960.

Max Endurance: Surfaced Submerged	 15500 miles 365 at 5 knots 110 at 10 knots	 7300 miles 158 at 24 knots[1] 224 at 15 knots[1] 100 at 5 knots on battery	 3000 miles 123 at 20 knots[1] 150 at 15 knots[1] 76 at 2 knots on battery	 - 300 at 24 knots 500 at 15 knots 4000 at 5 knots
Complement	57	27	19	27

[1] These endurance figures will be significantly lower for deep submarines.

Notes on Walter Turbine or Closed Cycle Engines for Submerged Propulsion [670]

For submerged propulsion oxygen had to be carried in the U-boat, either in the form of compressed, liquid oxygen or as Ingolin (HTP or hydrogen-peroxide, i.e. H_2O_2). 'Of these Ingolin is more economical, and convenient.' Liquid oxygen is very bulky and the bottles are very heavy. Ingolin is better in this respect, for it can be stowed in plastic tanks on the outside of the pressure hull. Ingolin is about 80% H_2O_2 and is stable at normal temperatures, provided it does not come into contact with a catalyst. It was very expensive, about £170 per ton. A Type XXVI would use about 16 tons per hour at high speed.

Walter Turbine. The Walter turbine at present is a geared gas and steam turbine driven by the combustion products of fuel (sulphur free) and oxygen obtained from Ingolin. The Ingolin is decomposed into steam and oxygen by passing over a catalyst, sufficient heat being evolved to heat the mixture to 450 degrees C. The steam and oxygen are led to a combustion chamber where fuel is injected and combined with the oxygen, more water is added to keep the temperature down and the resulting products of combustion and steam drive the turbine. The exhaust is steam and carbon dioxide. The steam is condensed and the CO_2 is dissolved in the sea, being trackless when the submarine is below 60 feet. Arrangements have to be made to prevent leaks of carbon dioxide into the submarine. The turbine room is, therefore, isolated by a bulkhead from the rest of the submarine and the pressure is kept lower. The overall efficiency is, in any case, low (17 per cent) and falls off with depth. At present the turbine is not worth using below 300 feet and cannot be used at all below 500 feet. (In the Type XXVI the turbine is only 12% efficient at 300 feet.)

Closed Cycle Engines. In the closed cycle engine, generally of diesel type, the exhaust is cooled, mixed with a proportion of oxygen and introduced into the engine again. The excess gasses are pumped overboard; being mostly carbon dioxide the exhaust is soluble in water. It is difficult to prevent an oil track with a reciprocating type engine, but the efficiency should be higher than the Walter turbine (30 per cent). At the end of the war, the Germans had made considerable progress in experiments with recycled engines. No U-boats were fitted with these engines, but the designs for alternative propulsion for the Type XVII had been produced.

[670] 'Notes on Walter Turbine or Closed Cycle Engines for Submerged Propulsion,' Appendix III to TASW.021/46, Revised, 4 May 1946, ADM 1/20960.

Appendix 7

The German View of the Employment of the Type XXI U-Boat, 1944 [671]

In December 1945 the Director of the Torpedo, Anti-Submarine and Mine Warfare Division, Naval Staff, Admiralty issued a précis of an article by Dönitz on the planned employment of the Type XXI U-boats. The précis is reproduced verbatim here, along with the introductory comments by DTASW.

Editorial Introduction [by DTASW]

A document was issued to all Senior Officers in the U-boat Command on 10 July 1944, when the building programme of the Type XXI had reached a sufficiently advanced stage for the German Naval Staff to take stock of the methods to be used by these U-boats for their attacks on trade. Consisting of some 40 pages, it set out the broad principles on which it was proposed these boats should operate.

This book is of great interest, written as it is by the leader of the biggest U-boat fleet in the world, and a digest of it is included in the pages that follow. The balance of the book is somewhat upset by this compression. But the main impression given is that the German methods proposed are sound, though they do not take sufficient account of the density of our air patrols, and the consequent difficulty for these boats to operate for any length of time on the surface.

The trend towards underwater warfare in which submarines operate wholly submerged can be clearly seen. Events would have proved to the Germans that the change to mass production of the Type XXVI must be made as soon as possible. Nevertheless, the permanent submersion of the enemy U-boats would have rendered most difficult their main task of finding the convoys, on which Dönitz lays so much stress, and it is interesting to speculate how this difficulty could have been overcome, without aid from a large number of reconnaissance aircraft.

The defensive tactics show the comparative ignorance of the German U-boat Command of the efficiency of our anti-submarine weapons and asdic sets. A U-boat "crawling" at 5 knots under attack would provide a fairly simple target.

The book does not pretend to include exact orders of the operation of the type XXI U-boats. Precise details would have followed later when operational experience had been gained by the first boats to go to sea.

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[671] 'Considerations Regarding the Operation of Type XXI, Précis of Text,' Grand Admiral Dönitz, [10 July 1944], Section III, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB, pp. 13-19. The full text can be found in: 'Operation of U-boat Type XXI (Document issued by Admiral Dönitz from Naval Staff Headquarters on 10 July 1944),' Department of Research Programmes and Planning, Admiralty, ACSIL Translation No. 542 (PG.18487), March 1952, FDS, Box 269, NHB.

CONSIDERATIONS REGARDING THE OPERATION OF TYPE XXI

Précis of Text

PREFACE

With this boat and other types, it will be possible to begin a new and successful U-boat war. This publication deals with the theoretical considerations regarding the operation of the type XXI boat in convoy attacks in the North Atlantic, and as a long range fighting boat in the Southern operational areas.

SECTION I – TYPE XXI ON PASSAGE

Strongly Air Patrolled Areas

Proceed submerged as a basic principle. Only surface to charge if it is impossible to Schnorkel.

(Here follows calculations of day's run at various states of charging of battery, and at various hours run on the surface.)

Average day's run (5 hours on surface) – about 150 miles.

Average day's run 21 hours Schnorkelling and crawling, 3 hours on surface – 114 miles.

Weakly Air Patrolled Areas

Average day's run (surfaced 11 hours) about 180 miles.

When to Schnorkel

(a) When no anti-submarine surface patrol is expected, Schnorkel at night. All round listening with hydrophones every 20 minutes. Use periscope by night to detect aircraft searchlights.

(b) Where surface anti-submarine patrol is expected, Schnorkel by day in good weather with periscope up. All round listening with hydrophones every 20 minutes. When periscope does not give sufficient safety, *Schnorkel at night.*

When Discovered by Aircraft

Radical alteration of course (at least 60°) from course last seen by enemy aircraft or from course assumed by enemy.

If arrival of anti-submarine groups is expected, make off at high underwater speed according to state of batteries.

Basic principle: Gain as large a distance as possible from last known position marked by the enemy. Remain submerged for a long time.

SECTION II – TYPE XXI AS A FIGHTING BOAT IN THE NORTH ATLANTIC

Preface

The type XXI has six torpedo tubes, which can be re-loaded in a short time. (The second salvo can be fired after five minutes, the third after 20 minutes.) Its fighting power is adequate to destroy powerful surface forces, but it has not sufficient strength to fight its way on the surface, and it must, therefore, sneak up to its target unobserved.

In the heyday of U-boat warfare, only a small number of sinkings was achieved despite many U-boats at sea, because the enemy located them and avoided our dispositions with his convoys.

The basic principle is, therefore: Remain unobserved at all costs in your operational area prior to attack. This you can do with the Type XXI.

Situation

U-boats must operate in the open sea, as it is impossible for a number of boats to wait at the starting point of the convoy routes owing to the good opportunities for countermeasures. When convoys are scattered in this way, the lack of aerial reconnaissance and the small visual range of the U-boat makes the finding of the enemy the most difficult problem. It is, therefore, correct to speak of our problems as being the expanse of the Atlantic.

The countermeasures, the quickness of their appearance, the number and excellence of available aircraft and ships and of their equipment mean that for the enemy there is no such thing as the expanse of the Ocean. For him it is merely a pond.

(a) TYPE XXI AS A SINGLE FIGHTING BOAT IN THE ATLANTIC

Each Type XXI represents a more serious threat to the enemy than any earlier U-boat. Each boat has to be intensively attacked and, therefore, causes a much greater splitting up of enemy defence forces. The struggle for mere existence is the operational area will be much easier than in comparison with present affairs.

Disposition

Attacking area will be ordered by operational control. It will be a large patrol area in which the boat is to proceed to and fro.

General Conduct

For maintaining the requirement for remaining unobserved, the boat is to surface or submerge by day or night, as required.

In general, in winter or in bad flying weather, surfacing may be allowed if FuMB (GSR) is available to five sufficient warning by day or night. FuMO ([Hohentwiel] radar) may only be used when the boat is detected and forced to remain on the surface owing to the state of the batteries and breakdown of the Schnorkel.

Conduct on Locating Enemy Aircraft

Increased air activity means the approach of a convoy. By day, therefore, dive and start Schnorkelling in anticipation of the chance of an attack.

By night, remain on the surface to charge, for on the surface the presence of the enemy may be more easily detected.

Conduct on Coming into Contact with the Enemy

(a) *By day, submerged*, on obtaining a hydrophone contact. Surface, if nothing sighted, and proceed along the last bearing, to conserve battery power.

Dive if aircraft approach, but otherwise continue on surface. When enemy R/T is heard, determine roughly course of the convoy and fetch a course to bring boat ahead of the convoy, at top speed. If necessary, submerge and proceed at top speed to gain bearing. If enemy aircraft are sighted, remain submerged and operate along presumed mean course of enemy. As soon as you are within visibility range, come to periscope depth.

(b) *By day, surfaced* – (Exceptional case). Dive at once and on obtaining hydrophone contact proceed submerged, to the attack.

(c) *By night, when surfaced* – (GSR warning). If it is aircraft, dive for a short while, otherwise remain on surface. Switch on own radar. Carry out all round HE sweep. Obtain picture by HE indications. Approach on the surface until the enemy is sighted. By night, as a basic principle, remain on the surface as long as possible. By skilful use of GSR, Balkon, hydrophones and MF/DF, surface attacks will frequently be possible.

(d) *By night when boat is submerged* – Indication by HE. Surface as necessary or remain submerged and carry out blind approach by HE and Nibelung gear. In general, after judging the weather and hydrophone listening conditions, CO must decide whether he is going to approach surfaced or submerged, crawling or noisy.

(b) TYPE XXI AS SINGLE FIGHTING BOAT UNDER THE COAST

In these areas, a constant and effective anti-submarine hunt can be easily arranged by the enemy at small expenditure of sea and air forces. Even more applicable is the basic principle.

Be sure to remain unobserved until you carry out your first attack. Targets are frequent in a traffic bottleneck, and, therefore, a good target can be selected.

Long endurance underwater and robust construction to withstand depth charging is necessary near the coast. Type XXI outstandingly fulfils these requirements.

Approach

Unobserved submerged as a basic principle, charging only with Schnorkel except in rough weather unsuitable for flying.

Conduct in Operational Areas

Only attack which chanced of firing are certain. If possible, charge through the Schnorkel under the protection of cliffs.

Continuous passage underwater brings in its train navigational difficulties, so seize every chance of fixing your position by periscope observation. Do not rely on being allowed to surface, for shore radar sets will be certain to pick you up.

SECTION III – TYPE XXI AS FIGHTING BOATS IN CONVOY ATTACKS

Basic Principles

The massing of the defences (escort of convoys) must be countered by a massing of the attackers. As long as the U-boats have to find the convoys themselves and thus solve the "problem of finding" themselves, a massing of the attackers is hardly possible. With Type XXI boats it will be possible to take up new dispositions, especially near the convoy departure points, unobserved and at a fair speed by Schnorkelling. By these means a certain depth of disposition will be possible, for avoiding tactics in there areas are scarcely possible. U-boats in these areas *must* remain unobserved.

(A) DISPOSITION IN GROUPS TO DISCOVER THE CONVOYS

Disposition at Points were the Traffic Converges

Scheme (a) – A disposition of many boats drawn up in a chess board pattern in the traffic bottleneck. Convoy sightings may not be passed on – use Kurier procedure. Only those boats directly approached by the convoys will be able to attack.

Scheme (b) – A disposition of several boats in the bottleneck as spies, with one or more groups just off the bottleneck, submerged. The spies are to report the convoys by W/T or Kurier to Operational Control. On receipt of the report from Control the groups shift to a position off the mouth of the bottleneck.

Disposition in Groups (Patrol Lines) in the Open Sea Area

(a) *Finding without being led on to the target by aircraft beacons.* It is assumed that we shall have air reconnaissance available. But though convoys can be discovered, they cannot be re-discovered, and beacon signals cannot be sent owing to strong fighter countermeasures. Procedure in 1942-43. Patrol lines across likely course of convoys. This was thwarted in 1943 by the enemy's location of our surfaced submarines and his avoidance of the patrol lines. The Type XXI has the advantage of the unobserved approach to the patrol line, so avoiding measures will be less effective.

    Disadvantage – Information of convoys is unreliable, and our dispositions have to be correspondingly broad. Only a few boats can get in contact with a convoy, and the remainder will not be able, as in 1943, to proceed ahead of the convoy on the surface.

(b) *Being led on to the target by beacon signals from aircraft.* Constant aircraft reconnaissance, as carried out in 1943, may not be possible, but if it is, the speedy and unobserved disposition of the patrol line by Type XXI and a reconnaissance over several days by aircraft will enable the patrol line to be shortened quickly and the distances between boats speedily reduced.

Carpet Disposition

Scheme – Disposition of the boats in carpets in a certain depth and breadth along the convoy's route. On receipt of an aircraft report, boats move off singly ahead of the convoy or form separate small patrol lines of 2-5 boats in order to increase the chance of finding the convoy abreast of the previous U-boat disposition ahead of the enemy's course. All this is done submerged, contact with convoy being obtained by hydrophone bearings only.

(B) CONDUCT FO THE BOAT IN THE DISPOSITION

Approach and Waiting in the Patrol Lines

Approach passage is to be carried out submerged as a basic principle, charging being done when Schnorkelling.

Waiting time is to be spent submerged, surfacing only when ordered, or when enemy is reported (as far as this is necessary).

Strict W/T discipline on the very long wave will be necessary.

Conduct on coming into Contact with the Enemy

(a) *By day, when submerged* – Report by Kurier, if possible, before attacking. If an attack is not possible, the boat's most important task is sending the report. If necessary, the boat must surface to do this. In the bottleneck disposition, attack first, then try to report.

(b) *By night, when submerged* – Except in the bottleneck, surface after observation, and report by Kurier.

Conduct of Remaining Boats on Receiving Enemy Report on Very Long Wave

(a) *By day* – If enemy can thus be reached, remain submerged using batteries economically, so as to sufficient capacity for the attack. Maintain contact by hydrophone gear.

    If enemy cannot be reached submerged, surface and try to get ahead until enemy aircraft become too dangerous. In the bottleneck, do not surface, and if necessary let the enemy go.

(b) *By night* – Do not surface in the bottleneck, and let the enemy go if necessary. In all other dispositions, surface and operate on the surface as long as possible.

SECTION IV – TYPE XXI AS A LONG RANGE FIGHTING BOAT

(Southern Atlantic and Indian Ocean)

Situation

The enemy relies on the import of raw materials from South America, South Africa and India. The routes are enormous, but the enemy has contrived protection for his convoys to a large extent.

Traffic – Convoys and independents proceed fast, and are routed to avoid U-boat areas.

Countermeasures – Air cover is widely given. New air bases have been built in great numbers. Surface forces, on the other hand, are comparatively weak, so their effectiveness is, therefore, slight.

Suitability of Type XXI as a Long Range Fighting Boat

Long Radius of Action

Endurances

Surfaced

6 knots...	...19,000 miles	11 knots...	...11,700 miles
7 knots...	...18,000 miles	12 knots...	...9,500 miles
8 knots...	...17,000 miles	13 knots...	...7,700 miles
9 knots...	...15,000 miles	14 knots...	...5,000 miles
10 knots...	...14,000 miles		

Submerged

With Electric Crawling Motors

5.5 knots...	...320 miles	5 knots...	...360 miles

Endurance increases at low speeds

With Main Motors

6 knots...	...280 miles	12 knots...	...60 miles
7 knots...	...210 miles	13 knots...	...50 miles
8 knots...	...160 miles	14 knots...	...40 miles
9 knots...	...135 miles	15 knots...	...30 miles
10 knots...	...110 miles	16 knots	...25 miles
11 knots...	...80 miles		

Short Times Required for Outward and Return Passages

Type IXC Boat

Lorient to 20°W (70 miles) at day's run of 140 miles	12 days
20°W to Panama (3,800 miles) at day's run of 168 miles	38 days
	50 days

Type XXI Boat

Lorient to 20°W (70 miles) at day's run of 140 miles	5 days
20°W to Panama (3,800 miles) at day's run of 168 miles	23 days
	28 days

To operational areas within 6,000 miles, therefore, a day's run of 160-170 miles will normally be possible on passage in the open sea.

Long Stay in Operational Area

Improved Living Conditions for the Crew, and less nervous strain, because new equipment, speed, strength and endurance of the boat makes an anti-submarine hunt less likely and less destructive.

It is possible to operate in areas that are strongly patrolled by aircraft.

Good Prospects to Success owing to High Underwater Speed

Summary

The short time required for the outward passage, good living conditions and adequate stocks of fuel and victuals permit the boat's torpedo fighting power to be utilised to the full. High underwater endurance using Schnorkel permits the boat to be used in heavily air-patrolled areas and ability to fire by means of her echo-ranging installation without using her periscope permit advantage to be taken of all chances of attack that offer.

SECTION V – THE BOAT ENGAGED IN ATTACKING

Basic Principles

(a) Type XXI is not a submersible but a submarine proper. On the surface it has poor fighting qualities; therefore, if an enemy has been discovered and can be reached in one underwater approach run, even if it means a reckless expenditure of battery capacity, do not hesitate to attack in one approach run and force a way through, if necessary. Even if you fire with a battery capacity of only 20 per cent. of the total, that is sufficient to last you through a long period of depth-charging.

(b) As you are unable to tell whether you will have a second chance of attaining an attacking position, you must hit with your first attack, by day or night.

(c) In spite of long range and LuT torpedoes, you must get as close as possible. The shorter the range, the more Legs-legs and the less chance of avoiding action. Balkon and Nibelung gear enable you to discover the enemy from a greater depth and attack him. But your eyes provide the best view.

(d) If you can carry out your attack as a surfaced attack by night or a periscope attack by day, try one of these methods first. You can always change to an attack with your technical eyes later.

(a) Day Attack

Attacks on independent are not considered though opportunities of them will be increased.

Unobserved Attack from Outside the Close Escort – Outer Attack

Firing position 3 to 5 miles distant for the heart of the convoy. Fire only from ahead to the beam. Aim at firing from directly ahead, for from there the best effect will be obtained by use of a LuT torpedo.

Slip through the remote escort unobserved, crawling being the best method from the point of view of HE. Attack by means of periscope shot or shot using Nibelung (this latter will not always be possible owing to the great range).

Long shots will be heard in hydrophones by surface vessels and result in avoiding action.

Conduct after Attack

Re-load immediately and fire a second "fan" after the first. If this cannot be done from the outer position proceed as follows:–

If you have been observed:–

(a) If your battery capacity permits, make for convoy at high speed, dive under the escorts and carry out a forced attack, using, Nibelung from the flank or inside the convoy. Proceed with the convoy, re-load and fire again.

(b) If your battery does not permit you to make for the convoy at high speed, go down to a considerable depth and fetch ahead by crawling under the convoy.

(c) If your battery capacity is low and it is not possible to run under the convoy, proceed ahead laterally to the convoy at crawling speed, in order to lose as little leeway as possible.

Assessment of Attacking Shot from Outside the Escort

Comparatively slight chances of hitting because:–

(a) Firing data inaccurate.

(b) Few effective LuT legs.

(c) Avoiding action by enemy will be effective.

Prospects of hitting will increase when 40 knot, 12,000 metre torpedo is produced.

Unobserved Attack from Within the Escort

(a) *Carrying out an attack at periscope depth, unobserved* – The same conditions will apply as earlier boats, but the Type XXI is a larger asdic-target. On the other hand, her silent speed "crawling" is 5 knots, and there fore she makes less noise.

(b) *Carrying out an attack from average depth by means of echo ranging installation. Unobserved attack without periscope* – First, survey the situation through the periscope. Approach run at 50 metres or deeper (using best depth for avoiding location), using HE gear chiefly, but also making slight use of Nibelung. Fire from depths of 30-50 metres as soon as you are in the best position (right ahead). When transmitting on Nibelung, remember that impulses must be as few and as weak as possible, to avoid betraying the boat's position. This does not apply when you are inside the screen.

(c) *Conduct after attack* – Re-load immediately and carry out a second attack, unless observed.

(d) *Comparison of echo ranging attack with periscope attack.*

Disadvantages – Les seen during approach run, uncertainty as to whether the boat has been discovered by the enemy.

Advantages – The boat is harder to discover and there is no chance of ramming.

(e) *Comparison between Type XXI and earlier boats when carrying our unobserved attack.*

Advantages – Boat can change position quickly, undetected by own HE, and she has a high turning speed. If discovered, she can quickly reach a safe depth quickly. Attacks are possible in heavy weather, when before they were not, and the enemies' defences are restricted in such conditions.

Underwater Attack as Forced Attack

Can only be carried out if battery capacity allows you to force your way through the enemy at high speed (12-15 knots).

Execution – Aim to dive under the outer screen unobserved, so that, after observation by the enemy, countermeasures do not start too early in the stretch between the outer and inner screens (which is a long stretch). Approach as close as possible to the close escort at "lowest high speed" required to get into a firing position. (It is necessary to determine your own noise ranges at various speeds. Noise tables for varying hydrophone conditions will have to be drawn up for each boat.)

As soon as you are observed, break through the screen at high speed, paying no attention to pursuit or depth charging.

If possible fire on your approach run. If it is not possible to get under the convoy and attack from below.

Shark Attack. Attack from Underneath the Convoy

Attack from underneath the convoy whilst you are under the protection of the merchant vessels. Attacking position ahead of astern, firing from a depth of 30 to 50 metres.

Your own high underwater speed enables you to keep up with the convoy, even at a convoy speed of 10 knots, for a long time, so that several attacks are possible. Danger from sinking ships is slight.

Conduct After Last Attack

After your last successful attack, proceed with the convoy for a few miles, then go down to a considerable depth and crawl. Then turn about and move off laterally astern of the convoy. Steer clear of the "after sweepers" by means of your

Nibelung and hydrophone gear. Chances of detection are slight, for their speed will be high and the after screen will be rescuing survivors. Surface as soon as possible and send your report.

(a) Night Attacks

Surfaced Attacks

It is assumed that the boat is in the vicinity of and ahead of the convoy. Stop periodically, carry out all-round listening with Balkon group then use Nibelung. Make use of the HE of the Nibelung. Take bearings of the locations you receive and use your Hohentwiel (radar) if necessary. Make use of bearings on convoy R/T wave, for the enemy is unable to forego using it. Plot locations on chart. You may be able to plot the disposition of the escort and even place the convoy.

Use Aphrodite.

Advantage of Type XXI

All-round listening is possible.

Ability to ascertain direction of location by the new Flieger.

Ability to ascertain type and location by subsequent operation of the Hohentwiel.

Greater degree of security and, therefore, freer operation, for not time is wasted in defensive dives.

If it is possible to carry out a surfaced attack in the old style, do so. If a destroyer makes for you, obtain firing data from Hohentwiel and if necessary, dive. If the boat is able to get away on the surface after the attack, try to do so. If discovered and pursuit is expected, dive, proceed beneath the convoy and attack again.

Submerged Attack at Night

If the boat is discovered during her approach run on the surface, of if she is certain to be forced under by the escort, she should remain on the surface for as long as possible to obtain a clear picture of the position. This is of great importance for the execution of a submerged attack at night.

The forced night attack is the ideal night attack. By night, owing to poor visibility and danger of ramming each other, it is practically impossible for the close escort ships to follow a boat which is approaching underwater at high speed, to attack her with depth-charges or to synchronise their alterations of course with hers. Underneath the convoy, the boat is as safe as if she were in a concrete shelter.

SECTION VI – TYPE XXI DURING DEPTH CHARGING

How Have Losses Due to Depth Charging Occurred so Far?

The cause, from information from returning prisoners, was as follows:–

(a) The boat was crawling at great depth. It was pursued for a long time with repeated depth-charges. The water penetrating through the pressure hull glands reached such proportions that it was not possible to pump it out with bilge pumps or compressed air. Water inside moved, and altered the trim, so that air had constantly to be used to regain trim. The penetration of the water into the battery released chlorine gas. The Commanding Officer had to surface before he ran out of air.

(b) The boat was crawling at great depth. She was subjected to a very long pursuit until both battery capacity and supply of compressed air were exhausted and she was forced to surrender.

(c) Owing to depth charging at great depth the pressure hull was penetrated (very rare).

(d) After long depth charging, the boat surfaced and found waiting escorts.

Comparison Between Powers of Resistance of Type XXI and Previous Types

Advantages – Able to seek greater depths (135 metres by 2½ safety factor).

High crawling speed.

High underwater speed makes it possible to control greater alternations in trim and in weight.

Large battery capacity makes it practically impossible to starve the boat out.

More water can be pumped out, for the boat is equipped with two depth bilge pumps.

Extremely good hydrophone gear and Nibelung permits a better check on movements of escorts.

Conduct During Depth Charging

(a) *Passive defence* – Seek great depth, roughly 300 metres, so that you can go still deeper if necessary. Make off at your high crawling speed on a mean course (making slight "zigs") in order to gain space. (The maximum range of asdic is 5,000 metres.)

If you are force to go at a higher speed, and thus allow the enemy to hear you, carry out large scale avoiding movements.

Alter course again at the very moment you change for high speed to crawling.

If you cannot shake off the enemy, use all means of evasion, i.e., alterations of speed, course and depth and eject Bolde and Sieglinde (new SBT).

Active Defence

The days of sitting impotently in the cellar are past and gone. By use of high speed, Bolde and big alterations of course, you may throw ships off the scent, and so get into a good attacking position for firing *Zaunkönig* (Gnat).

Appendix 8

Walter Submarine Tactics, 1946 [672]

<u>Possible Lines of Development of Submarine Tactics</u>

In this appreciation a submarine of the following type and capabilities is envisaged.

Schnorkel fitted and diesel driven with normal electric submerged assisted by Walter propulsion.

Endurance	(a) 150 miles at 24 knots	Walter Gear
	(b) 220 miles at 15 knots	Walter Gear
	(c) 150 miles at 3 knots	Battery
	(d) 7,000 miles at 8-10 knots	Schnorkel Diesel

(a) and (c) or (b) and (c) will be the limit of its endurance completely submerged and without the use of Schnorkel.

2. Is torpedo armament will be the equivalent of existing types by the torpedo armament will improve by 150% on existing torpedoes, that is to say capable of 50 knots for 10,000 yards or 40 knots for 20,000 yards. It is most improbable that any new armament will be fitted but its communications, detecting devices and torpedo control will be greatly improved. It is also possible that some form of short period transmission underwater telegraphy may be fitted.

3. In contemplating any change in tactics that such submarine may employ their potentialities must be reviewed alongside those of 1944 submersibles; the following features stand out:–

(a) Greatly increased tactical speed.

(b) Effective hitting from a markedly increased range.

(c) Ability to fire torpedoes from greater depths.

(d) Increased diving depth.

(e) Increased protection from attack.

(f) Increased screening against echo, sound or magnetic detection.

(g) Unsuitability for surface operations.

(h) Reduced strategical speed.

(i) Reduced radius of action.

4. The great increase in tactical speed can only be made by the sacrifice of endurance, surface speed and surface sea keeping qualities.

5. In view of the extensive air and radar over in the future these submarines will have to live nearly all their time at sea under water, coming to the surface only in exceptional circumstances. The mental effect of this on the submarine crews is likely to be such that it will be desirable to reduce the length of patrol below the two months that was normally undertaken in the past.

6. Their speed on passage will be low compared with the war time submersible. If paragraph 5 is found to be true the result will be an appreciable reduction in operational radius.

7. It is likely therefore that the submarine will tend to operate nearer to focal points and avoid the open oceans where its strategical speed will be insufficient for long

[672] 'Possible Lines of Development of Submarine Tactics,' TASW.816/46, 'Appendix "A" to "Joint Paper on...Convoy Defence",' P.W. Burnett, for DTASW, and F.J. Finnigan, Director of Operations, Sub-SAWC/II C.30414/D of Ops, [July 1946], Box 96, RG 313, NARA2.

range interception. This probability is supported by the fact that its increased power of evading detection and destruction will encourage it to operate in the face of a stronger opposition, particularly when the chances of success are great.

8. As in the past the submarine will have to find its targets in the same way, by observation, listening, radar, intelligence and enemy reports (principally from co-operating aircraft). No new factor can at the moment be foreseen.

(a) Observation

This can only be carried out on the surface or at periscope depth. As the future submarine will not attempt to keep on the surface, and periscope watch gives a poor lookout in any but good weather its powers of observation will be in no way superior to its predecessors.

(b) Its powers of listening will improve but in view of the possible progress in silencing ships the net result is unlikely to show any great gain for the submarine.

(c) Radar and Search Receiver

It is only reasonable to assume that in any future war the opponent of the submarine will be at least as well equipped in radar as we are likely to be. The user of radar from a submarine is an inherent risk in disclosing the submarine position, or at least its presence. It cannot be assumed that the submarine will use radar before the risk of its detection will not materially affect attack, that is to say only in the very late stages of the attack it is likely to be used. A Search receiver in the submarine may be of value, but the extent of this value will depend on the use of radar by surface ships.

(d) Intelligence is an incalculable factor but there appear no grounds for belief that it will be either better or worse than in the past.

(e) Enemy reports are likely to be at least as comprehensive as in the past but to receive these reports (unless transmitted by another submarine by underwater signals) the recipient must be at periscope depth or on the surface. In order to keep W/T watch the submarine on patrol will therefore generally be within range of magnetic detection from aircraft if it intends to use these reports. To avoid this danger of detection the only answer will be to go deep. Such a policy combined with its poor strategical speed must lead to the submarine patrolling where the targets come to her rather than seeking the targets. This again implies a tendency to concentrate in focal areas.

9. In summarising the above it appears that the submarine must rely primarily on observation and listening. If a good periscope lookout is kept she should be able to go deep in good time to avoid magnetic detection from the air.

10. The foregoing attempts to show the strategical situation of the future submarine. The factors already quoted also effect its tactical employment.

11. In the tactical field the following new course of action lie open to the submarine:–

(a) Use of its underwater speed for approach and attack

(b) Use of its underwater speed for evasion after attack

(c) Use of increased hitting range.

(a) Use of underwater speed in approach and attack

For a submerged submarine of the old type to achieve a close attack it had to start within an arc of 20° of either bow of the target. The use of Schnorkel cruising speed will rather more that double this arc.

If very strong air cover prevents the use of Schnorkel, the same results can be achieved by the discrete use of Walter propulsion, though the submarine must of course retain a margin of high speed for evasion after the attack.

Whether or not submarines will use high speed to pass through the screen must remain unanswered until more is known about its chances of detection through the use of speed. An important factor in this question is that throughout its attack, if operating alone or if directing other submarines, it must keep itself informed as well as possible of the latest movements of the target and screen. The surest and safest way to do this is undoubtedly by visual observation through the periscope. This must be done at slow speed if detection is to be avoided. The other methods of getting the required information, i.e., by radar, asdic or listening inevitable risk disclosing the submarine's presence or obtaining doubtful or confused information.

It therefore appears likely that the passage through the screen and the final stages of the attack must be directed, at least, from a submarine at or close to periscope depth and proceeding at slow speed. If the submarine is operating as a single unit of is the directing submarine in the case of divisional attack; it may use brief bursts of high speed or great depth or both solely for the purpose of evasion of the screen.

(b) The use of high speed for evasion after attack

It seems certain that this will be used extensively as with intelligent use everything is to be gained and nothing lost. For example, if an A/S vessel is in contact with a submarine and heading away from the submarine at 15 knots, a two minute burst of 24 knots by the submarine will put it out of asdic range, and the search will have to start again. In view of the fact that in the immediate future Walter propulsion cannot be used safely near the surface (owing to the track it leaves), or at all at great depths, it appears likely that the submarine underwater evasive tactics will consist of bursts of high speed at depths of about 150 feet on Walter propulsion, interspaced with periods of slow speed electric propulsion at varying depths between periscope depth and maximum diving depth (1,000 feet). In the event of a divisional attack it appears likely that in the subsequent escape, submarines will spread at high speed in pre-determined sectors if only to enlarge the area in which the escorts must make their search.

(c) The use of increased hitting range

The principle that the closer one is to the target the better the chance of hitting must always hold good but as with the progress from the arrow to the shell and so to the long range guided missile, so will increased hitting range be made use of by the submarine where it pays to do so.

The future long range pattern running or homing torpedo will increase the chances of success at the previous maximum range by at least 150%. It will also allow a good chance of hitting at a range of 50% more than the previous maximum.

If this long range is used it must mean extending the screen to a greater distance from the target and unless a far greater number of escorts are used it will decrease the chance of the submarine being detected before or after the attack. This must be a highly tempting proposition for the submarine. Against the use of long range is one powerful factor; the submarine will be unable to get accurate enough information on which to stage a successful attack. Periscope visibility or radar worked from a transmitter just above the surface cannot give useful information at ranges appreciably beyond 7 miles. This can only be overcome by close range tactical direction of the submarine.

12. All interested nations in the past have experimented with the pack or divisional attack. Chiefly because of inadequate inter-submarine communications little use of them has been made. Though the Germans attacked in numbers their attacks were not cohesive and were only tactically directed to a small extent.

13. Advantages of the divisional attack:–

(1) Concentration of fire power

(2) Initial detection and confusion of the enemy's A/S effort

(3) In the later sates of a war with the quality of submarine CO's begins to decline all effort can be directed by a competent leader.

Disadvantage of the divisional attack:–

A failure in the control of the division may result in a failure of all the submarines in the division.

14. Improved methods of inter-submarine communication will make the divisional attack possible in the future. The factors mentioned in paragraph 13 combined with a desire to sue increased hitting range appear to indicate that the divisional attack will become a practice in the future, not necessarily habitual but to be used as the situation demands.

The ability to fire torpedoes from greatly increased depth will be a material factor in the divisional attack. It is possible to visualise a scheme where submarines patrol in groups of two or three stationed in a vertical plane, one beneath the other, say at periscope depth, 150 feet and 300 feet, with the tope one directing the division and communication with the leader of a similar division up to 15 miles away.

In this way directional underwater sound-telegraphy would be received by all members of the division together and an attack could be directed accurately even if the leader of one division was out of sight but within torpedo range of the target.

Should such a division be detected by the escort considerable confusion would be caused to the escort owing tot the multiplicity of echoes. If detection took place before the attack two out of three submarines would almost certainly get away to pursuer their attack unmolested. If after their attack, their chances of evasion by the use of high speed would be enhanced.

Whether submarines are operated in close tactical formation or not the directed attack from a submarine outside its own visibility range of the target, remains very much a possibility.

16. <u>The use of high underwater speed to continue the attack</u>

After one attack, submarines will be able to maintain contact with the target while reloading. It is clear that they will do so unless driven off. The question as to what tactics they will employ is these circumstances must cause consideration to be given to their attempting to remain under the convoy. The chief advantages of this are that they should be undetectable and will be close to a convenient firing position after reloading. Against this is the fact that station-keeping would be difficult if not impossible and the fear of a towed or intermittently dropped barrage would be a powerful deterrent. Opinion on this question is likely to be strongly divided and different lines of action will be pursued by different submarines.

17. To sum up, it appears that the following innovations will be brought about:–

(a) Use of high underwater speed for evasion

(b) Use of high underwater speed for gaining contact

(c) Attack at long range

(d) Attack on concentration where suitable

(e) Avoid the use of radar and thus attack principally by day, patrolling deep at night to avoid magnetic detection

(f) Seek focal points in deep water for its operations.

Appendix 9

Submarine Nomenclature, 1947 [673]

Confidential Admiralty Fleet Order 312/47 is reproduced below:

In order to avoid confusion between the different types of submarine at present in being or contemplated, the names in Column I of the table given below are in future to be used.

2. The term 'submarine' will remain the generic title for all types.

I	II	III
Type Name	Meaning	Existing Submarines of this Type
'True Submarine'	A submarine which will require no connection with the atmosphere while at sea and will be driven by some form of closed cycle propulsion, possibly atomic energy. It will never need to surface or use a snort.	No vessels of this type exist.
'Intermediate Submarine'	The submarine of high submerged speed driven by HTP or closed cycle propulsion. Has to use a snort periodically, but need never surface.	HMS *Meteorite* (ex *U-1407*). Projected German Type XXVI.
'Intermediate Submarine (B)'	The submarine of high-submerged speed driven by batteries. Has to use a snort periodically but need never surface.	German Type XXI. Fast 'S' conversions represent this type in submerged speed but not other qualities.
'Submersible (Snort fitted)'	The present submarine of slow underwater speed but fitted with the snort. Need never surface but will gain considerable mobility by doing so.	All German operational types at the end of the war; (Types VIIC, IXC principally) British A and T classes fitted with snort. HMS *Sirdar*.
'Submersible'	Vessels with similar characteristics to those that have up to the present been called 'submarines'. Need to surface to charge.	All other British submarines of A, T and S classes.

[673] 'CAFO 312 – Submarines – Nomenclature,' TSD.61/47, 26 September 1947, NHB; 'Submarines – Nomenclature,' DDOps(M)/132, 3 February 1948, AIR 2/5950.

Bibliography

A note on sources:

Where quotations are given, or citations made, they have been taken verbatim from the original sources, except where – occasionally – odd spellings were used, or where, for example, dates are expressed in different formats, these have been silently corrected. Other additions by the author are denoted, as usual, by square brackets.

Sources were gleaned from a number of archives. Often the source is available in a number of these institutions, but the citations given here are those where the particular document was first found by the author. All the documents listed were used in the construction of the narrative.

Archives Used

AL	Admiralty Library, Ministry of Defence
AWM	Australian War Memorial, Canberra
BRNC	Britannia Royal Naval College, Dartmouth
CCAC	Churchill College Archives Centre, Cambridge
DERA	Information Centre, Defence Evaluation and Research Agency, Winfrith (now DSTL/Qinetiq)
DHH	Directorate of History and Heritage, Department of National Defence, Ottawa, Canada
DNH	Directorate of Naval History, Canberra
IWM	Imperial War Museum, London
LHCMA	Liddell Hart Centre for Military Archives, King's College, London.
MLJ	M. Llewellyn-Jones Collection
NAA(C)	National Archives of Australia (Canberra)
NAA(M)	National Archives of Australia (Melbourne)
NAC	National Archives of Canada, Ottawa
NA(K)	National Archives (formerly Public Record Office), Kew
NARA2	National Archives and Records Administration 2, College Park, Maryland
NHB	Naval Historical Branch, Ministry of Defence
NHC	Naval Historical Center, Navy Yard, Washington
NMM(G)	National Maritime Museum, Greenwich
NMM(W)	National Maritime Museum, Woolwich
OA, NHC	Operational Archives, Naval Historical Centre, Navy Yard, Washington (see NHC)
RNM	Royal Naval Museum, Portsmouth
RNSM	Royal Naval Submarine Museum, Gosport

Primary Sources

NA(K) – National Archives (formerly Public Record Office), Kew

ADM 1. Admiralty and Secretariat Papers

'Convoy on the Outset of War with Germany,' Plans Division, 19 February 1938, ADM 1/9501.

Minute, Admiral Lord Chatfield, First Sea Lord, 8 March 1938, ADM 1/9501.

Minute, Vice Admiral W. James, DCNS, 7 March 1938, ADM 1/9501.

Draft Letter, PD.06700/38, May 1938, ADM 1/9501.

Minute, Captain T.S.V. Phillips, D of P, 3 March 1938, ADM 1/9501.

'Review of the Situation at Sea, December 1939, Vice Admiral Binney's Committee,' Vice Admiral T.H. Binney, IDC.38, 8 December 1939, ADM 1/9793.

'A Proposal for a Type of "Q" Ship to Work in Conjunction with Anti-Submarine Vessels, Vice Admiral Binney's Committee, IDC.1,' Vice Admiral T.H. Binney, 18 September 1939, ADM 1/9793.

'[Minelaying by the Enemy off British Ports], Vice Admiral Binney's Committee, IDC.12,' Vice Admiral T.H. Binney, 12 October 1939, ADM 1/9793.

'Definition of the Word "Asdics",' Commander F.J. Walker, RN, for Captain A/S, HMS *Osprey*, Cdr/MH/7, 18 December 1939, ADM 1/9880.

Minutes, Captain A.G. Talbot, DASW, 8 December 1939, Captain C.H.J. Harcourt, DOD(H), 19 December 1939, Captain W.L. Jackson, DTSD, 21 December [1939], [Captain L.E. Holland], AHO to First Sea Lord, 12 March 1940, ADM 1/10468.

'Review of Methods of Dealing with the U-boat Menace,' Captain A.G. Talbot, DASW, 29 February 1940, ADM 1/10468.

Minute, Captain J.H. Edelsten, D of P, PD.08182/39, 26 November 1939, ADM 1/10084.

Minute, Admiral H.M. Burrough, ACNS, 7 March 1940, ADM 1/10468.

'Review of Methods of Dealing with the U-boat Menace,' Captain A.G. Talbot, DASW, 29 February 1940, ADM 1/10468.

Minute, Captain C.S. Daniel, D of P, 20 March 1940, ADM 1/10468.

[Captain L.E. Holland], AHO to First Sea Lord, 12 March 1940, ADM 1/10468.

'Magnetic Submarine Detector (MAD),' Admiralty.134/1942, 1942, ADM 1/11741.

'MAD, Question of Fitting in our A/S Aircraft,' DACD, ACD.33/42, 12 September 1942, ADM 1/11741.

Minute, DNAD, 15 May 1939, ADM 1/12141.

'Anti-Submarine Striking Forces, [Revised Form of Draft],' Memorandum by Tactical Division, Naval Staff, June 1938, ADM 1/12141.

Minute, D of P, 22 March 1939, ADM 1/12141.

Minute, Captain D.A. Budgen, RN, D of TD, 13 April 1939, ADM 1/12141.

'Anti-Submarine Striking Forces,' S.H. Philips, Admiralty, M/TD.117/38, 27 July 1938, ADM 1/12141.

'Anti-Submarine Striking Forces,' Admiral Dudley Pound, Commander-in-Chief, Mediterranean, Med.01169/01243/2, 7 December 1938, ADM 1/12141.

'Escort Carriers: Duration of Employment,' BAD, (M.054165/43), 26 March 1943, ADM 1/12857.

'Instructions for the Operation of Escort Carriers,' Admiral Max Horton, Commander-in-Chief, Western Approaches, Memorandum No. WA.0756/36, 7 February 1943, ADM 1/13081.

'Hints on Escort Work,' 1943-1944, ADM 1/13749.

'A/S Warfare in Relation to Future Strategy, Memorandum by the First Lord of the Admiralty,' War Cabinet, Anti-U-Boat Warfare, AU(43)1, 5 January 1943, ADM 1/14793.

'Minutes of a Meeting held at ACHQ Liverpool on 3rd October 1944 to discuss a Programme of Schnorkel and other Trials and Practices,' Admiral Horton, 4 October 1944, ADM 1/16121.

'Type of German U-boats Required for Post War Experiments and Tests,' Admiral (Submarines), Northways, to Secretary of the Admiralty, 15 October 1944, ADM 1/16384.

Minute, G.B.H. Fawkes for Admiral (Submarines), 27 April 1945, ADM 1/16384.

Minute, M Branch, 23 October 1944, ADM 1/16384.

Minute, DASW, 2 April 1944, ADM 1/16495.

'Fast U-boats,' Captain HMA/SEE, Fairlie to DASW, 28 March 1945, ADM 1/16495.

'Deep and/or Fast U-boats,' DASW, ASW.468/44, 24 March 1944, Captain HMA/SEE, Fairlie to DASW, 'Deep and/or Fast U-boats,' 30 March 1944, Captain HMA/SEE, Fairlie to DASW, 'Deep and/or Fast U-boats,' 10 April 1944, ADM 1/16495.

'Deep and/or Fast U-boats,' Captain HMA/SEE, Fairlie to DASW, 10 April 1944, ADM 1/16495.

'Western Approaches Tactical Unit Annual Report - 1944,' Captain Gilbert Roberts, 18 December 1944, ADM 1/17557.

Captain G.H. Roberts, RN, Western Approaches Tactical Unit, to C-in-C, WA, 30 May 1945, ADM 1/17561.

'Visit to *U-2008*, Type XXIII, 250 tons (May 24 1500-1700),' Appendix V to Captain G.H. Roberts, RN, Western Approaches Tactical Unit, to Commander-in-Chief, Western Approaches, 30 May 1945, ADM 1/17561.

'Search for three experimental U-boats, Type XVII, May 26,' Appendix X to Captain G.H. Roberts, RN, Western Approaches Tactical Unit, to Commander-in-Chief, Western Approaches, 30 May 1945, ADM 1/17561.

'HE Listening versus Transmitting by Asdic – Operational Considerations,' The Captain, HMS *Osprey*, to DASW, No. 636/86, dated 26 January 1945, ADM 1/17569.

J.R. Thompson for DMWD, Admiralty, to various, 16 May 1945, ADM 1/17583.

Captain R.J.R. Dendy, RN, Captain HMA/SEE, Fairlie, to Director of Miscellaneous Weapons, Admiralty, No. D.1802, 12 March 1945, ADM 1/17583.

'Hedgehog and Squid Probabilities,' J.R. Thompson, DMWD/20/61, 19 April 1945, ADM 1/17583.

'Hedgehog and Squid Probabilities (Addendum to DMWD/20/61),' J.R. Thompson, DMWD/20/61A, 16 May 1945, ADM 1/17583.

'Surface Craft Tactical Countermeasures to Type XXI U-Boats,' Research Report No. 93, ASWORG/206 (LO)1380-45, 4 May 1945, ADM 1/17588.

'The Use of Squid against the 25 knot U-Boat,' [Captain N.A. Prichard], DASW, [ASW 945/45], 30 June 1945, ADM 1/17591.

'The Use of Squid against the 25 knot U-Boat,' Captain N.A. Prichard, DASW, to Captain HMS *Osprey* and Captain HMA/SEE, ASW 945/45, 2 July 1945, ADM 1/17591.

'*Osprey* Tactical Unit – Policy,' [Captain] N.A. Prichard, DASW, to The Captain, HMS *Osprey*, ASW1044/45, 25 July 1945, ADM 1/17591.

[Captain] N.A. Prichard, DASW, to The Captain, HMS *Osprey*, ASW1044/45, 30 July 1945, ADM 1/17591.

'Operation "CW": Analysis for NW Approaches, 25 August – 17 October 1944,' W.H. McCrea, DNOR, 1 December 1944, ADM 1/17653.

Director of Anti-Submarine Warfare Division, Naval Staff, to The Captain HMS *Osprey*, ASW/AUD.2018/45, 27 August 1945, ADM 1/17653.

Captain C.D. Howard-Johnston, DAUD, and Captain N.A. Prichard, DASW, Ref: D.559 (Draft), 5 August 1945, ADM 1/17653.

'Survey of A/U Operations in UK Coastal Waters, July 1944 – May 1945,' [W.H. McCrea], DNOR, 13 July 1945, ADM 1/17653.

'Planning,' [C.D. Howard-Johnston], 12 June [1945], ADM 1/17653.

NID L.C. Report No. 999, H. Clanchy, DDNI(H), 16 June 1945, ADM 1/17653.

DASW, to The Captain HMS *Osprey*, ASW/AUD.2018/45, 27 August 1945, ADM 1/17653.

Manuscript: giving the considerations for the use of the schnorkel by British or enemy submarines in the Far East, [anon, c. 6 July 1945], ADM 1/17653.

Draft Minute, DASW, 26 July 1945, ADM 1/17659.

'Report of operations of *U-2326* and interrogation of captain: analysis and results of surface and air anti U-boat measures in Rosyth Command between 23 April and 8 May,' 1945, ADM 1/17661.

Minute, VCNS to First Sea Lord, 3 September 1945, ADM 1/17743.

'Torpedo, Anti-Submarine and Mine Warfare Division – Institution,' H.V. Markham, Office Memorandum No. 394, CE.58514/45, 24 September 1945, ADM 1/17743.

'Instructions for the Director of Torpedo, Anti-Submarine and Mine Warfare Division,' Office Memorandum No. 147, CE.58776/45, 29 March 1946, ADM 1/17743.

Admiral (Submarines) to the Secretary of the Admiralty, No.1038/SM.4021, 12 July 1945, ADM 1/18328.

Admiralty to Flag Officer (Submarines), M.06993/45, 27 August 1945, ADM 1/18328.

'First of Class Trials – Type XXI and Type XXIII U-boats,' Admiral (Submarines) to the Secretary of the Admiralty, No.1311/SM.3530, 7 September 1945, ADM 1/18328.

Minute, L. Solomon, DNOR, 1 November 1945, ADM 1/18328.

Minute, Director of Operations Division, 2 November 1945, ADM 1/18328.

Minute, DTASW, 10 November 1945, ADM 1/18328.

Minute, E.W. Pratt, for Director of Scientific Research, 18 December 1945, ADM 1/18328.

Minute, R.C Boyle, for DTM, 4 January 1946, ADM 1/18328.

Minute, W. Marshall, Head of M II, 20 January 1946, ADM 1/18328.

W. Marshall, [Head of M II], Admiralty, to Admiral (Submarines), M.06993/45, 31 January 1946, ADM 1/18328.

'Minutes of a Meeting held at Northways on 25 June 1945: Trials to be carried out in, and with, U-boats,' n.d., ADM 1/18557.

'Tactical Trials with Captured German U-boats,' DASW, [28] August 1945, ADM 1/18557.

'Appendix. Remarks on First of Class Trials and Deep Dive of *U-2326*,' Enclosure No. 3 to Admiral (Submarines') letter No. 1681/SM.3530 of 24 November, 1945. ADM 1/18557.

'Trials with Captured German U-boat – Type XXIII', Commander John Grant, Commander (D), Londonderry Flotilla, HMS Fame, D.14/21/1, 18 October 1945, ADM 1/18557.

'Trials with Mk. XXIII U-boat No.2326. Short Title "Twetub",' HMA/SEE, Fairlie, 30 August 1945, ADM 1/18557.

'Report on Tactical Trials with Type XXIII U-Boats' Covering Commanding Officer, *U-2326*'s letter dated 21 October 1945, Captain (S/m), Third Submarine Flotilla, HMS Forth, to Admiral (Submarines), No. TSF.1947/3720, dated 6 December 1945, ADM 1/18557.

'Enclosure C to Commander (D), Londonderry Flotilla, HMS Flame's No: D.14/21/1 dated 18 October 1945,' ADM 1/18557.

'*U-2326* First of Class Trials. September 1945,' Admiral Submarines, HMS Dolphin, Gosport, n.d., ADM 1/18557.

'*U-2326* – First of Class Trials,' Admiral (Submarines) to the Secretary of the Admiralty (Copy to Headquarters, Coastal Command), No. 1681/SM.3530, 24 November 1945, ADM 1/18557.

Mr Richmond Walton, Deputy Secretary, Admiralty to Rear Admiral Spencer S. Lewis, Chief of Staff, United States Naval Forces in Europe, Grosvenor Square, London, M.010398/45, dated 25 July 1946, ADM 1/18557.

Enclosure to Admiral (Submarines) Letter No. 1415/SM.3577, 4 October 1945, covering the Report by Lieutenant J.S. Launders, DSO, DSC, RN, Commanding Officer of ex-German *U-3017*, 30 August 1945, ADM 1/18949.

Board of Inquiry Report, HMS *Amphion* at Barrow-in-Furness, 3 September 1945, ADM 1/18949.

'Board of Inquiry to Investigate the Explosion Onboard *U-3017* on 29 August 1945 (Captain (S/m), Third Submarine Flotilla's No. 6306/3739 of 13 July 1945),' G.E. Creasy, Rear Admiral (Submarines), 1415/SM.3577, 4 October 1945, ADM 1/18949.

'Explosions in U-boat Batteries,' Captain (S/M), Loch Ryan, to Admiral (Submarines), 201/2529, 2 September 1945, ADM 1/18949.

'Staff Requirements for A/S, A/A and A/D Frigates,' File TSD 2036/46, 6 December 1946, ADM 1/19230.

'Meeting held by VCNS on 28 December, 1945, to consider the number of submarines that could be kept in service in the Post-War Fleet,' Head of Military Branch II, 5 February 1946, ADM 1/19301.

'Meeting held by Vice Controller at 1430 on 24 January 1946 to consider further the number of Submarines that could be kept in the Post-War fleet,' M.023/46, M. Platt, Head of M. II, 18 February 1946, ADM 1/19301.

'Russian Naval Tactics,' NID/16, 10 October 1946, ADM 1/20030.

Minute, Philip Currey, for DTSD, 29 April 1947, ADM 1/20030.

Minute, E.M. Gollin, Director of Operational Research, 1 April 1947, ADM 1/20030.

Minute, Peter Cazalet, for D of P, 22 April 1947, ADM 1/20030.

Minute, G.N. Oliver, ACNS, 5 May 1947, ADM 1/20030.

Minute, [Vice Admiral Sir Rhoderick McGrigor, VCNS], 7 May [1947], ADM 1/20030.

Minute, [Captain] Ashbourne, DTASW, 1 November 1946, ADM 1/20030.

Minute, DNAW, 25 July 1946, ADM 1/20045.

Minute by D of P, 26 August 1945, PRO: ADM 1/20045.

'Formation and Organisation of Naval Operational Research Department,' CE.60648/1946, 1941-1946, ADM 1/20113.

Minute by F. Brundrett, MA, DDSR, 17 December 1945, ADM 1/20113.

'The Middleton Steering Committee: Report on the Torpedo Anti-Submarine Branch,' Rear Admiral G.B. Middleton, CBE, Captain C.L. Robertson, John G. Lang, PAS(NP) and K. W. Matthews, Secretary, 22 December 1945, ADM 1/20207.

Memorandum by G.N. Oliver, ACNS, 31 December 1946, ADM 1/20384.

'Ability of the Submarine of the Future to Make Contacts,' [Captain Lord Ashbourne, DTASW, 28 January 1947], ADM 1/20384.

'Proposed Paper for Policy and Plans Sub-Committee [Air Reconnaissance for Submarines of the Future],' [Captain A.N.C. Bingley, DNAW, 26 June 1947], ADM 1/20384.

'Prevention of Enemy Air Reconnaissance Co-operating with Submarines: Appreciation,' [Captain E.H. Shattock, DNAW, 5 February 1947], ADM 1/20384.

Minute, G.N. Oliver, ACNS, 18 April 1947, ADM 1/20384.

'Proposed Paper for Policy and Plans Sub-Committee [Air Reconnaissance for Submarines of the Future],' [Captain A.N.C. Bingley, DNAW, 26 June 1947], ADM 1/20384.

'The Submarine as an Anti-Submarine Vessel: Part II – The "Fighter" Submarine,' DTASW, TASW.289/47(2), 24 November 1947, ADM 1/20414.

'Submarines – Possibilities as Fighters,' 1947-1949 and 1954, ADM 1/20414.

'Joint Paper on Sea and Air Aspects of Fleet Defence against Submarines,' F.J. Finnigan, Director of Operations, Air Ministry, Captain G. Willoughby, DNAW and Captain Lord Ashbourne, DTASW, Admiralty, TASW.4261/46, [1 November 1946], ADM 1/20936.

'The Development of A/S Warfare,' TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960.

'Development of the Submarine,' Annex A to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960.

'Policy Review of Methods of Attacking Submerged Submarines by Surface Vessels and (Appendix) by Aircraft', Annex B to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960.

'A Review of the Methods of Attacking Submerged Submarines by Aircraft,' Appendix to Annex B to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960.

'Summary of DTASW's Investigation on A/S Warfare,' Annex C to TASW.021/46, Revised Edition, 4 May 1946, ADM 1/20960.

'Progress Report: Shipborne A/S Weapons,' TASW.038/46, [5 September 1946], ADM 1/20960.

Secretary of the Admiralty to various, M/TASW.047/46, 5 September 1946, ADM 1/20960.

'Performance of U-boats,' Appendix I and Appendix II to TASW.021/46, Revised, 4 May 1946, ADM 1/20960.

'Notes on Walter Turbine or Closed Cycle Engines for Submerged Propulsion,' Appendix III to TASW.021/46, Revised, 4 May 1946, ADM 1/20960.

'A/S Problems of the Future – Attack-at-Source and Harbour Defence,' G.N. Oliver, Office of the Chief of Naval Staff, 8 December 1947, ADM 1/21546.

'Requirements for an HTP Operational Submarine,' Flag Officer Submarines 705/S/M.068 dated 8 September 1952 with Notes by Admiralty Divisions and Departments,' [DTSD, 12 November 1952], ADM 1/23729.

'Joint Anti-Submarine School, Londonderry. Progress Report – Summer Term, 1952,' C-in-C, Plymouth, M.024475/52, ADM 1/23733.

Minute by Captain V.D'A. Donaldson, DTASW, 13 October 1952, ADM 1/24139.

N. Abercrombie to Commanders-in-Chief and Flag Officer (Submarines), etc., M.TASW.289/47, 8 January 1948, ADM 1/24407.

'Long Range Detection of Submarines using VLF Hydrophone Equipment,' DTASW, 20 June 1952, ADM 1/24506.

Minute, Captain E. Shattock, DNAW, 14 July 1948, ADM 1/24518.

'Guidance on Future Tactical Problems for Naval Aircraft,' Captain G. Barnard, RN, The Director, RN Tactical School, TC No. 166/1/5, 18 June 1948, ADM 1/24518.

Minute, Captain H.G. Dickinson, for D of P, 20 July 1948, ADM 1/24518.

'Historical Research Memorandum No. 1: Surface and Air Anti-Submarine Escort of Shipping in Convoy, and Anti-Submarine Transit Area Patrols in Two World Wars,' Historical Section, Admiralty, May 1953, ADM 1/24962.

'Report on 1950 exercises with submarines in ASW operations,' ADM 1/25252.

'ASW priority,' Admiralty letter M/TASW.289/47, 8 January 1951, ADM 1/25252.

'Submarine Development,' DTASW, TASW.330/47, November 1947, ADM 1/27215.

'Ingolin (Hydrogen Peroxide). Underwater Propulsion Development,' 1945-1946, ADM 1/27774.

Minute, J. Kingcome, Engineer-in-Chief, 14 December 1945, ADM 1/27774.

Minute, Engineer-in-Chief, 30 January 1946, ADM 1/27774.

'A Review of Past Submarine Tactics and a Forecast of Probable Future Enemy Submarine Tactics,' DTASW, TASW.329/47, June 1948, ADM 1/30840.

ADM 116. Admiralty and Secretariat Cases

Minute, [Commander] I.M.R. Campbell for Director of Naval Intelligence, 15 March 1945, ADM 116/5202.

Minute, G.B.H. Fawkes for Admiral (Submarines), 16 November 1945, ADM 116/5500.

'Proposal to refit and re-commission *U-2518* on return by the French Navy,' [Captain] Ashbourne, DTASW, TASW.44/47, 7 February 1947, ADM 116/5500.

'Minutes of the 1st Meeting of the Tactical and Training Sub-Committee and the 1st Meeting of the Technical Investigation Sub-Committee...,' SAWC/II/2/46 and SAWC/III/2/46, 13 May 1946, ADM 116/5614.

'Minutes of the Fourth Meeting of the Tactical and Training Sub-Committee of the Joint Sea/Air Warfare Committee...,' J.L. Crosbie and G.R. Carver, Joint Secretaries, Sub-SAWC/II/9/46, 19 July 1946, ADM 116/5614.

'Minutes of the 4th Meeting of the Technical Investigation Sub-Committee, 8 August 1946,' Sub-SAWC/III/7/46, 12 August 1946, ADM 116/5614.

'To A and B Members of Joint Sea/Air Warfare Sub-Committees: Correction to Paper on Sea and Air Aspects of Search and Convoy Defence (C.30414/D of Ops),' G.R. Carver, NSR, NSR/28, 3 August 1946, ADM 116/5614.

'Distribution of Paper: Anti-Submarine Problems of the Future, TASW.4666/47,' Minute Assistant Director A/S to DTASW, File TASW 5224/47, 18 December 1947, ADM 116/5614.

'Minutes of the Seventh Meeting of the Tactical and Training Sub-Committee of the Joint Sea/Air Warfare Committee held on 7 November 1946, in Room 764, Alexandra House, Kingsway,' Sub-SAWC/II/19/46, 8 November 1946, ADM 116/5614.

'Minutes of the Sixth Meeting of the Technical Investigation Sub-Committee of the Joint Sea/Air Warfare Committee held in Room 14/I Air Ministry, Whitehall on 4 December 1946,' Sub-SAWC/III/13/46, 7 December 1946, ADM 116/5614.

'JSAWC – Technical Investigation Sub-Committee, 6th Meeting,' Minute, AD(T), Minute Sheet TASW 4382/46, 29 November 1946, ADM 116/5614.

'Fitting of High Speed Dome to Destroyers,' Ship Design Policy Committee, SDPC(49)14, 25 May 1949, ADM 116/5632.

'Development of Machinery for the Fast Underwater Propulsion of Submarines,' Naval Staff answers to points raised by E-in-C, initialled "R.E.", 1 September 1949, ADM 116/5632.

'Report on Torpedo, Anti-Submarine, Ordnance and Electrical Branches by Rear Admiral H.C. Phillips,' March 1944, ADM 116/5692.

'Remarks by Commander-in-Chief, Home Fleet,' Enclosure No. 6 to 'Exercise "Sunrise",' Admiral McGrigor, Commander-in-Chief, Home Fleet, No.393/940/105/10, 28 March 1949, ADM 116/5779.

Minute, [Commander H. MacLean], for DTSD, May 1949, ADM 116/5779; Captain C.E.E. Paterson, DTASW, 30 May 1949, ADM 116/5779.

Minute, Captain Lord Ashbourne, DTASW, TASW.214/[45], 18 October 1945, ADM 116/5853.

'Joint Sea/Air Warfare Committee: Minutes of the Fifteenth Meeting of the Tactical and Training Sub-Committee held in the Air Ministry on Wednesday 23 June 1948,' Sub-SAWC/II/49/48, ADM 116/5819.

'Annex A: Radar Maritime Aircraft,' Air Commodore G.W. Tuttle, DOR(E), C.32400/46/Pt.3., to DCD, 7 July 1948, ADM 116/5819.

'Report by DOR(E) on Sonobuoys – British/American Standardisation,' Air Commodore G.W. Tuttle, DOR(E), C.34223/47 and Sub-SAWC/II/54/48, 4 August 1948, ADM 116/5819.

Minute, D of P, 20 August 1947, ADM 116/5966.

Minute, USS, 23 October 1947, ADM 116/5966

'Assumptions as to Risk of Future War and Target Date for Re-equipment of the Fleet,' 1947-1948, ADM 116/5966.

ADM 137. Admiralty, Historical Section, Records used for Official History, First World War.

'Offensive Action against Submarines Attacking Convoys,' Vice Admiral C.H. Dare, Admiral, Milford Haven, No. 1273/096U, 6 September 1918, ADM 137/2655.

[Conference held on 28 May 1918 to Discuss Offensive Action against Submarines Attacking Convoys],' Secretary, Admiralty, M.011781, 5 July 1918, ADM 137/2655.

'Measures Required to Meet the Submarine Situation in the Future,' [Captain C. Fuller, D of P, PD.0105, 28 August 1918], ADM 137/2709.

ADM 173. Submarine Logs.

'Monthly Log of HM Submarine *Seraph*, Month of June 1944,' ADM 173/18699.

'Monthly Log of HM Submarine *Seraph*, Month of September 1944,' ADM 173/18701.

'Monthly Log of HM Submarine *Seraph*, Month of October 1944,' ADM 173/18702.

ADM 186. Admiralty: Publications.

'Mercantile Convoys: General Instructions for Port Convoy Officers, Ocean and Destroyer Escorts, and Commodores of Convoys,' CB648(2), 18 October 1918, ADM 186/40.

'Annual Report of TAS Schools, 1946,' UWD, CB4486, UW.05407/47, 24 October 1947, ADM 189/66.

'Exercise "ZL", Combined Fleets, 7-15 March 1935,' in, 'Exercises and Operations 1935,' CB1769/35(1) and (2), September 1937, ADM 186/157.

'Methods Recommended for Carrying out Searches for Hostile Submarines,' CB1238, October 1916, ADM 186/373.

'Progress in Torpedo, Mining, anti-submarine and in allied subjects, 1924,' CB0975, 1925, ADM 186/444.

'Progress in Torpedo, Mining, Anti-Submarine, and Chemical Warfare Defence, 1931,' CB3002(1931), 1932, ADM 186/491.

'Progress in Torpedo, Mining, Anti-Submarine Measures, and Chemical Warfare Defence, 1932,' CB3002/32, 1933, ADM 186/500.

'Progress in Torpedo, Mining, Anti-Submarine and Chemical Warfare Defence,' CB3002(34), 1934, ADM 186/515.

'Progress in Torpedo, Mining, Anti-Submarine Measures, and Chemical Warfare Defence, 1935,' CB3002/35, 1935, ADM 186/522.

'Progress in Torpedo, Mining, Anti-Submarine Measures, and Chemical Warfare Defence,' CB3002(1936), 1936, ADM 186/540.

'Progress in Torpedo, Mining, Minesweeping Anti-Submarine Measures and Chemical Warfare Defence, 1937,' CB3002/37, 1937, ADM 186/541.

ADM 189. Torpedo and Anti-Submarine School Reports.

'Annual Report of TAS Schools, 1948,' UWD, CB4486(48), UW.05088/1949, January 1949, ADM 189/68.

'Eleventh TAS Liaison Meeting: Minutes,' Part 4, 'Evaluation of Fast A/S Frigate Conversions,' paper read by Captain M. Le Fanu, DSC, RN, Captain (D), Third Training Squadron, 9-11 September 1952, ADM 189/235.

'Eleventh TAS Liaison Meeting: Minutes,' Part 7, 'Paper I – Integrated Asdic Equipment in Escorts,' paper read by Lieutenant Commander A.J.R. Foster, DSC, RN, Underwater Detection Establishment, Portland, 9-11 September 1952, ADM 189/235.

'Eleventh TAS Liaison Meeting: Minutes,' Part 8, 'Paper II – Progress and Trials of SHF/DF Equipment,' paper read by Lieutenant Commander R.E. Buller, RN, HMS *Mercury*, 9-11 September 1952, ADM 189/235.

'Eleventh TAS Liaison Meeting: Minutes,' Part 13, 'Paper I – Review of Soviet Naval and Air Forces and their TAS Roles; Paper II – Soviet Underwater Weapons: Discussion,' 9-11 September 1952, ADM 189/235.

ADM 199. War History Cases and Papers.

'Anti-Submarine Striking Forces,' Memorandum (Amended 1 December 1938, TD.355/38) Tactical Division, LDD/M.09345/39, June 1938, (Reprint corrected September 1939), ADM 199/124.

'General Information and Instructions for A/S Striking Forces,' C-in-C, Plymouth, Memorandum No. W.0550/11, 21 September 1939, ADM 199/124.

'[Conduct of Aircraft Carriers and Destroyers when Engaged in Anti-Submarine Operations],' S.H. Phillips, Secretary, Admiralty, M.015382/39, 28 November 1939, ADM 199/124.

Minute, Captain A.G. Talbot, DASW, December 1939, ADM 199/124.

Minute, Captain M.J. Mansergh, DTD, 29 December 1939, ADM 199/124.

Minute, Captain D.A. Budgen, D of LD, LD.0502/39, 24 September 1939, ADM 119/124.

'Report of A/S Operation by 8th DF,' C-in-C, HF, 1707/HF.1335, M/010685/39, 23 September 1939, ADM 199/126.

'HMS *Ark Royal*, Proceeding and Destruction of German S/M *U-39*,' C-in-C, HF, 1654/HF.1207, M/010146/39, 17 September 1939, ADM 199/126.

Minute, Captain D.A. Budgen, RN, Director of Anti-Submarine Warfare, M.010685/39, 10 October 1939, ADM 199/126.

'[HMS *Hermes* Report of Proceedings 14-18 September 1939],' Captain F.E.P. Hutton, No. 55/11/007, 21 September 1939, ADM 199/137.

Minute, G.M.B. Langley, for Director of Naval Air Division, 9 October 1939, ADM 199/137.

Minute, Captain D.A. Budgen, DASW, 17 October 1939, ADM 199/137.

Minute, J.H. Edelsten, D of P, 25 October 1939, ADM 199/137.

'Narrative and Remarks by Senior Officer,' Section I, Part 1, 'Report of Proceedings,' Commander P.W. Burnett, RN, HMS *Braithwaite*, Ref. No. 1A/10, 20 February 1945, ADM 199/198.

'Operation "Victual" Passage of Convoys JW59 and RA59A to and from North Russia,' Captain C.D. Howard-Johnston, DAUD, 15 November 1944, ADM 199/351.

'Report of Proceedings, 10th Escort Group, HMS *Spey*, 8-24 February 1944,' Commander G.A.G. Ormsby, RN, Ref. 5/9, 26 February 1944, ADM 199/358.

'Standing Orders for U-boat Hunts off Northern Ireland (Short Title: Operation "CW"),' Commander-in-Chief, Western Approaches, 24 February 1944, ADM 199/468.

[Report of Proceedings, 1-14 July 1944], Captain H.T.T. Bayliss, HMS *Vindex*, Vindex 2100/0133, 15 July 1944, ADM 199/497.

'Report of Proceedings for the Period 10 July 1944 to 19 July 1944,' Captain W.P. Carne, Captain HMS *Striker*, 2542/01/4, 19 July 1944, ADM 199/497.

'Report of Proceedings of U-boat Action off Cape Wrath, HMS *Vindex*,' ACOS, 912/OS.0253, M.08326/44, 1 August 1944, ADM 199/497.

'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501.

'On a Ship in Convoy being Torpedoed in an Area where the U-boat can Bottom,' Appendix IV (7 April 1945) to, 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501.

'Air Operations,' in Appendix VII to, 'Orders for Anti-U-boat Operations in Coastal Waters of the Western Approaches Command (Short Title: Operation "CE"),' Admiral Max Horton, C-in-C, WA, WA.3036/020/7, [M.010815/44], 11 October 1944, ADM 199/501.

Commander P.W. Burnett to Captain C.D. Howard-Johnston, 12 November 1944, ADM 199/501.

'[Report of Proceedings, Convoy ON202], Commander P.W. Burnett, RN, Senior Officer, C2 Group, HMCS *Gatineau*, 28 September 1943, ADM 199/353.

Message DASW to various, 2024A/11 October, 11 October 1942, ADM 199/1732.

'HMS *Venturer* – Report of Eleventh War Patrol,' Lieutenant J.S. Launders, RN, No. SC 4110, 15 February 1945, ADM 199/1815.

'An Analysis of the Operation of Support Groups in the North Atlantic (Period 14 April – 11 May 1943),' Anti-U-boat Division, Admiralty, 15 June 1943, ADM 199/2020.

'Analysis of U-boat Operations in the Vicinity of Convoy SC130, 18-21 May 1943,' Anti-U-boat Division, Admiralty, 15 July 1943, ADM 199/2020.

'An Analysis of the Operation of Support Groups in the North Atlantic (Period 5 May – 12 June 1943),' Anti-U-boat Division, Admiralty, 15 July 1943, ADM 199/2020.

'Monthly Anti-Submarine Report, February 1943,' 15 March 1943, ADM 199/2060.

'Monthly Anti-Submarine Report, April 1944,' 15 May 1944, ADM 199/2061.

'Monthly Anti-Submarine Report, June 1944,' ADM 199/2061.

'Monthly Anti-Submarine Report, August 1944,' 15 September 1944, ADM 199/2061.

'The Type XXI U-boat - A Provisional Appreciation,' in, 'Monthly Anti-Submarine Report, August 1944,' 15 September 1944, ADM 199/2061.

'Monthly Anti-Submarine Report, September 1944,' ADM 199/2061.

'Monthly Anti-Submarine Report, October 1944,' ADM 199/2061.

'Monthly Anti-Submarine Report, November 1944,' 15 December 1944, ADM 199/2061.

'Defence against Submarine Attack,' CID Paper 1318-B [Extract], March 1937, ADM 199/2365.

ADM 204. Admiralty Research Laboratory: Reports and Notes.

'Sub-sonic Hydrophone Investigation,' Admiralty Research Laboratory, Teddington, ARL/N.5/95.27/D, 31 August 1949, ADM 204/2841.

ADM 205. First Sea Lord Papers.

'Vice Admiral Binney's Committee, IDC.2,' Vice Admiral T.H. Binney, Imperial Defence College, 21 September 1939, ADM 205/1.

Captain A.G. Talbot, Director of Anti-Submarine Warfare, to First Sea Lord, [M.013984/39], 23 November 1939, ADM 205/2.

Note, Churchill to First Sea Lord, 20 November 1939, ADM 205/2.

First Sea Lord to Director A/S Division, D.P., M.013984/39, 21 November [1939], ADM 205/2.

'Anti-Submarine Training,' Captain R. Kerr, Captain (D), Second Destroyer Flotilla, [13 June 1939], ADM 205/3.

'Note on Relation Between the Use of Aircraft to Give Cover to Convoys and in the Bay,' P.M.S. Blackett, CAOR, 22 March 1943, ADM 205/30.

'Review of U-boat Results in Inshore Waters,' Admiral Edelsten, ACNS(UT), UT.37, 30 November 1944, ADM 205/36.

'Anti-U-Boat results inshore in Western Approaches Command for the period 1 September 1944 to 31 January 1945,' C.D. Howard-Johnston, DAUD, D.353, 4 February 1945, ADM 205/44.

'Forecast of the U-Boat Campaign during 1945,' Andrew Cunningham to Vice Admiral G.C. Jones, CB, Chief of the Naval Staff of Canada, 25 January 1945, ADM 205/44.

'Policy and Fleet Tactical Training,' R. Dick, DTSD, TSD.4580/48, 14 July 1948, ADM 205/69.

ACNS to First Sea Lord, ACNS/263, 20 October 1948, ADM 205/69.

'Maritime Policy as it affects Exercise "Trident",' P.L. Vian, Fifth Sea Lord, 10 September 1948, ADM 205/69.

'Maritime Policy as it affects Exercise "Trident",' Fraser, First Sea Lord, 14 September 1948, ADM 205/69.

'Maritime Policy,' P.L. Vian, Fifth Sea Lord, 15 September 1948, ADM 205/69.

'Maritime Policy,' Fraser, First Sea Lord, 29 September 1948, ADM 205/69.

'Maritime Operations,' T.M. Brownrigg, D of P, 28 September 1948, ADM 205/69.

'The Proposed Policy for Build-up of Naval Aviation after the Outbreak of War,' Appendix II to 'Maritime Operations,' T.M. Brownrigg, D of P, 28 September 1948, ADM 205/69.

Admiral R. McGrigor, Commander-in-Chief, Home Fleet to Admiral of the Fleet Lord Fraser of North Cape, First Sea Lord, 24 November 1948, Section 5, ADM 205/70.

ADM 213. Admiralty Centre for Scientific Information Liaison: Reports.

'Half-Yearly Scientific and Technical Progress Report,' HM Underwater Detection Establishment, Portland, 1946 (2), ADM 213/362.

ADM 217. Station Records: Western Approaches.

Commodore (D) Western Approaches to DAUD, 16 July 1944, ADM 217/90.

'Battle of the Atlantic: Recent Changes in Enemy Tactics,' CSO(M), C-in-C, WA, Hush Message, 142141A December 1943, ADM 217/358.

'HMS *Helmsdale*: Report of Proceedings of B4 Escort Group of Convoys OS64 and KMS38, from 5-17 January 1944,' ADM 217/358.

'Report of Proceedings, Tenth Escort Group, 26 December 1944 to 3 January 1945,' Commander P.W. Burnett, RN, No. 1A/8, 4 January 1945, ADM 217/373.

[Report of Proceedings of 9 Escort Group for period 7 October to 3 November 1944], Commander Layard, Senior Officer, EG9, 7 November 1944, ADM 217/728.

'HMS *Conn*, Report of Proceedings, 11 January to 2 February 1945,' Lieutenant Commander Raymond Hart, DSC, RN, Senior Officer 21 Escort Group, 5 February 1945, ADM 217/755.

ADM 218. Royal Naval Scientific Service: A B Woods Papers.

'Submarine Location: Notes in Reply to First Sea Lord's Enquiry, October 1929,' 1921-1929, ADM 218/273.

'Report on Methods of Submarine Location (Draft notes for reply to 1st Sea Lord enquiry dated October 1929),' [A.B. Woods, Admiralty Research Laboratory], 9 November 1929, ADM 218/273.

B.S. Smith, HMS *Osprey*, to Director, Scientific Research & Experimental Department, Admiralty, 14 August 1929, ADM 218/273.

ADM 219. Directorate of Naval Operational Studies: Reports.

'Some Operational Implications of a Homing Torpedo,' L. Solomon, Report 36/43, 1 June 1943, ADM 219/52.

'Detection of U-boats in the English Channel and Approaches (Rough analysis of the period D to D+10),' E.J. Williams and L. Solomon, Report No. 48/44, 19 June 1944, ADM 219/131.

'Remarks on *Philante* Exercises, 29 July 1944,' W.H. McCrea, DOR/44/60, 3 August 1944, ADM 219/142.

'Note on the value of "Snort" to U-boats,' L. Solomon and E.J. Williams, DNOR, Report No. 62/44, 19 August 1944, ADM 219/144.

'A/S Operations against Snort U-boats Working Inshore,' E.J. Williams, DNOR, Report No. 66/44, 29 August 1944, ADM 219/148.

Commander E.H. Mann (Ret), DASW, to DAUD, 6 September 1944, ADM 219/148.

'Type XXI U-boat (A Provisional Appreciation),' E.J. Williams, DOR/44/68, 4 September 1944, ADM 219/150.

'Inshore Operations,' Appendix (ii), to, 'Type XXI U-boat (A Provisional Appreciation),' E.J. Williams, DOR/44/68, 4 September 1944, ADM 219/150.

'Anti-Snort Trials,' E.J. Williams, DNOR, Report No. 70/44, 5 October 1944, ADM 219/152.

'Notes on A/S Trials with a Fast Submarine,' W.H. McCrea, Report No. 72/44, 9 October 1944, ADM 219/154.

'Trials on a Fast Submarine: Interim Report to DNOR from his observer at Fairley and "Rockabill" trials,' HMS *Black Swan*, 22 October 1944, ADM 219/158.

'Notes on A/S Trials with a Fast Submarine, "Rockabill", 10-30 October 1944,' [W.H. McCrea], Report No. 80/44, 11 November 1944, ADM 219/160.

'Prospects in the U-boat War,' E.J. Williams, ADNOR, Report No. 81/44, 17 November 1944, ADM 219/161

E.J. Williams to ACNS(UT), 17 November 1944, ADM 219/161.

'Effect of High Submerged Speed on U-boat Tactics,' W.H. McCrea, NORD, Report No. 20/45, 23 April 1945, ADM 219/225.

'OKM Interrogation Unit – Report by DNOR's Representatives,' DOR 45/25, n.d., ADM 219/230.

'Theoretical study of the development of a U-boat pack attack,' W.H. McCrea, DOR 54/41, 18 May 1945, ADM 219/244.

'A/S Training for Operations in Inshore Waters,' W.H. McCrea, DNOR, Report No. 83/45, 8 January 1945, ADM 219/283.

C.D. Howard-Johnston, DAUD to W.H. McCrea, DNOR, 8 January 1945, ADM 219/283.

'Counter-measures to the Acoustic Torpedo,' ASW Operations Research Group, Tenth Fleet, United States Navy, Memorandum 42, 20 November 1943, ADM 219/566.

'Transit Offensives and the Inshore U-boat,' I.E. Tweedie, Department of Operational Research, Report No. 29, August 1953, ADM 219/607.

'Pack Tactics by Submarines (Summary),' E.J. Williams, JTS-C No. 10, 21 February 1944, ADM 219/631.

ADM 223. Admiralty: Naval Intelligence Division and Operational Intelligence Centre: Intelligence Reports and Papers.

'U-boat Methods of Combined Attack on Convoys, 1 February to 31 October 1941,' Naval Section [GC&CS, Bletchley Park], ZIP/ZG/116, 10 November 1941, ADM 223/1.

'U-boat Trend, Period 21-28 August,' J.W. Clayton, DDIC, 28 August 1944, ADM 223/20.

'Anti-U-boat Operations Inshore,' Captain C.D. Howard-Johnston, DAUD, Ref: D.218, 11 September 1944, ADM 223/20.

'Experience Gained during Anti-U-boat Inshore Operations,' Captain C.D. Howard-Johnston, DAUD, Ref: D.218, 11 September 1944, ADM 223/20.

'Review of U-boat Results in Inshore Waters, Period 1 July to 31 October,' Captain C.D. Howard-Johnston, DAUD, Ref: D.294, 23 November 1944, ADM 223/20.

'Notes on Support Group Operations, September, 1943 – January, 1944,' [Leon Solomon], CAOR, OIC/SI.919, 6 April 1944, ADM 223/172.

'Note on U-boats Fitted with Snort,' DDIC and LS/EJW, DNOR, OIC/SI.1036, 11 August 1944, ADM 223/172.

'U-boat Situation, Week Ending 28 August 1944,' Captain Rodger Winn, RNVR, OIC/SI.1062, n.d., ADM 223/172.

'U-boat Situation, Week Ending 11 September 1944,' Captain Rodger Winn, RNVR, OIC/SI.1078, n.d., ADM 223/172.

Admiralty to C-in-C, Plymouth, C-in-C, WA, AOC-in-C, Coastal Command, etc., 271405B/August, 27 August 1944, ADM 223/203.

'Notes on Two U-boat Cruises in the English Channel,' DDIC, DAUD, DNOR, OIC/SI/1021, 24 July 1944, ADM 223/261.

'Note on Escort Group Operations in the English Channel, 6 June – 10 July 1944,' LS/EJW, DNOR, 20 July 1944, ADM 223/261.

'On the Value of Squash in Pack Attacks,' [Leon Solomon], DNOR, OIC/SI1254, [19 March 1945], ADM 223/261.

'Inshore Operations by U-boats, August – September 1944,' LS/EJW, DNOR, OIC/SI.1108, n.d., ADM 223/315.

ADM 229. Admiralty: Department of the Director of Naval Construction: Directors' Papers.

'Notes Taken at Deputy Controller's Meeting, Tuesday, 13th June, 1944,' C.S.L. [Charles Lillicrap], 14 June 1944, ADM 229/34.

ADM 234. Navy Reference Books: BR [Books of Reference] Series.

'Conduct of Anti-U-Boat Operations: Part IV, Air and Surface A/S Searches and Striking Forces' DASW, ASW 3078/43, BR1679(4), June 1944, ADM 234/293.

'Arctic Convoys, 1941-1945,' Naval Staff History, Second World War, Battle Summary No. 22, Historical Section, Admiralty, CB3305(4), [BR1736(44)], TSD.296/52, 7 December 1954, ADM 234/369.

'The Defeat of the Enemy Attack on Shipping, 1939-1945: A Study of Policy and Operations, Vol. 1B (Plans and Tables),' Historical Section, Admiralty, BR1736(51)1B, [CB3304(1B)], 16 April 1957, ADM 234/579.

ADM 239. Navy Reference Books: CB [Confidential Books] Series.

'Protection of Shipping at Sea (Provisional Issue),' Plans Division, Naval Staff, CB01764(39), February 1939, ADM 239/40.

'Progress in Tactics: 1947,' DTSD, CB03016/47, 17 October 1947, ADM 239/143.

'Exercise "Spearhead",' in, 'Progress in Tactics: 1947,' DTSD, CB03016/47, 17 October 1947, ADM 239/143.

'Progress in Tactics, 1948,' DTSD, TSD.108/48, CB03016/48, 30 November 1948, ADM 239/144.

'Progress in Tactics. 1951,' DTSD, TSD.141/51, CB03016(51), 21 June 1951, ADM 239/145.

'Progress in Underwater Warfare, 1949,' DTASW, TASW.30/50, CB04050(49), 17 July 1950, ADM 239/274.

'The First Experience of A/S Actions with Intermediate (B) Submarines,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274.

'A/S Practices of HMS *Battleaxe*, *Crossbow*, *Scorpion* and *Broadsword* with HM Submarine *Scotsman* in the North Channel in January and February, 1949,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274.

'A/S Practices of HMS *Battleaxe*, *Crossbow*, *Scorpion* and *Broadsword* with USS *Dogfish* in the North Channel in February and March, 1949,' in, 'Progress in Underwater Warfare, 1949,' CB04050(49), 17 July 1950, ADM 239/274.

'Progress in Underwater Warfare, 1951: Part 2, Anti-Submarine,' TASW.149/52, CB04050(51), 1 December 1952, ADM 239/275.

'Progress in Underwater Warfare, 1951: Part 3, Torpedo,' TASW.149/52, CB04050(51), 1 December 1952, ADM 239/275.

'Inshore Operations,' in, 'Admiralty Convoy Instructions to Escorts (Short Title ACI), General Sections 1-6,' Part XII, DAUD, CB04234(44), April 1945, ADM 239/345.

'Admiralty Convoy Instructions to Escorts (Short Title ACI), 1944,' Part XII, 'Inshore Operations,' Anti U-Boat Division, August 1944, ADM 239/345.

'Progress in Underwater Warfare, 1946,' DTASW, TASW.1453/46, CB04050(46), March 1947, ADM 239/420.

'Progress in Underwater Warfare, 1947,' DTASW, TASW.116/48, CB04050(47), 8 October 1948, ADM 239/421.

'Progress in Underwater Warfare, 1948,' DTASW, TASW.53/49, CB04050(48), 10 September 1949, ADM 239/422.

'The First Experiences of A/S Actions with Intermediate (B) Submarines: Addendum to CB04050(48) – Progress in Underwater Warfare, 1948,' DTASW, TASW.312/49, CB04050(48)(N), 1 December 1949, ADM 239/423.

'Exercise "Trident", Volume I,' CB004520, April 1949, ADM 239/489.

'A Survey of the Tasks of the Maritime Forces in Support of the Three Pillars of Our Strategy,' Item 13, in, 'Exercise "Trident", Volume I,' CB004520, April 1949, ADM 239/489.

'Cause of U-boat Sinkings – 2 World War,' Diagram 20 in, 'Exercise "Trident", Volume II,' CB004521, April 1949 (issued 23 January 1950), ADM 239/490.

'The Defence of Ocean Shipping in 1957,' Vice Admiral G.N. Oliver, CB, DSO, President RN College, Greenwich, Item 17, in, 'Exercise "Trident", Volume II,' CB004521, April 1949 (issued 23 January 1950), ADM 239/490.

'A Joint Planning Staff Conference before the Outbreak of War,' Item 28, and 'The Defence of a Convoy against Submarine Attack: Demonstration by the RN Tactical School,' Item 30, in, 'Exercise "Trident", Volume II,' CB004521, April 1949 (issued 23 January 1950), ADM 239/490.

'Progress in Tactics, 1949,' DTSD, TSD.109/49, CB03016(49), 29 September 1949, ADM 239/565.

ADM 259. Underwater Detection Establishment.

'Echo and HE Characteristics of the Submarine *Scotsman*,' J.W. McCloy, HM Underwater Detection Establishment Report No. 95, October 1951, ADM 259/29.

'The Application of Lofar Techniques to Sonobuoys,' D.A. Hanley, UDE Pamphlet No. 293, September 1953, ADM 259/205.

'Type 144. Trials of Operating Procedure,' HMA/SEE, Fairlie, Internal Report No. 159, December 1943, ADM 259/382.

'The Experimental Four Square Asdic Set,' HMA/SEE, Fairlie, Internal Report No. 230, 9 November 1945, ADM 259/429.

ADM 283. Department of Scientific Research and Experiment: Reports.

'Dependence of Submarine Propeller Noise on Depth of Submarine,' Director of Scientific Research, SRE/SM/7/0, 19 June 1944, ADM 283/13.

AIR 1. Air Historical Branch Records, First Series.

'Employment of Aeroplanes for Anti-Submarine Work,' Colonel Williamson, Commanding No. 18 Group, RAF, 14 August 1918, AIR 1/642/17/122/252.

Minute, Director, Air Division, AD.3845, 26 August 1918, AIR 1/642/17/122/252.

AIR 2. Air Ministry: Registered Files.

Minute, Group Captain V.C. Darling, RAF, DDOps(M), 30 September 1946, AIR 2/5950.

Reference Sheet, 'Defence of Fleet Units against Submarine Attack,' C.E.E. Paterson for DTASW, TASW.380/48, 19 August 1948, AIR 2/5950.

'Defence of Fleet Units against Submarine Attack,' DTASW, TASW.380/48, August 1948, AIR 2/5950.

'The Tactical Employment of Patrol Groups,' Sub-SAWC/II/63/48, [TASW.404/48], [30 September 1948], AIR 2/5950.

'Submarines – Nomenclature,' DDOps(M)/132, 3 February 1948, AIR 2/5950.

'Joint Sea/Air Warfare: Minutes of the Thirteenth Meeting of the Tactical and Training Sub-Committee of the Joint Sea/Air Warfare Committee, held in the Air Ministry at Richmond Terrace on Thursday 27 November 1947,' Commander J.W. Hale and Wing Commander C.B. Gavin-Robinson, Sub-SAWC/II/33/47, 1 December 1947, AIR 2/9677.

A.B. Birnie to M.M. Low, A/M.01938/46, 1 March 1948, AIR 2/12249.

AIR 15. Coastal Command, 1936-1965.

[Principles of Anti-Submarine Patrol by Aircraft], J. Lawson, Admiralty, M/NAD.398/37, 31 August 1937, AIR 15/38.

[Principles of Anti-Submarine Patrol by Aircraft], G.F. Cotton, Admiralty, A/NAD.13/39, 23 February 1939, AIR 15/38.

'Convoy Organisation,' Wing Commander R.N. Waite, for C-in-C, Coastal Command, S.9066/8/28A/Air, 22 April 1939, AIR 15/38.

Minute, Wing Commander R.N. Waite, Wing Commander Plans, to SASO, 10 February 1939, AIR 15/38.

'Coastal Command Manual of Anti-U-Boat Warfare,' May 1944, AIR 15/294.

'Report by RAF Observer in HMS *Viking* during period 24 April – 6 May 1944,' HQ No. 19 Group, 30 May 1944, AIR 15/557.

'Sonobuoy Range Tests,' 15 July 1944, AIR 65/115; 'The Use of Sonobuoy Equipment,' HQ Coastal Command Training Instruction No 28, dated 9 June 1944, AIR 15/584.

'Joint Sea/Air Warfare Committee: Tactical and Training and Technical Investigation Sub-Committees,' Joint Secretaries, Sub-SAWC/II/2/47 and Sub-SAWC/III/2/47, 13 January 1947, AIR 15/786.

'Minutes of the 1st Meeting of the Tactical and Training Sub-Committee and the 1st Meeting of the Technical Investigation Sub-Committee...,' Cdr G.R. Carver and W/Cdr J.L. Crosbie, Sub-SAWC/II/2/46 and Sub-SAWC/III/2/46, 13 May 1946, AIR 15/786.

'Minutes of Eleventh Meeting of the Technical Investigation Sub-Committee of the Joint Sea/Air Warfare Committee, held in the Admiralty Room 37, Old Block, on 22 October 1947,' Wing Commander C.B. Gavin-Robinson and Commander J.W. Hale, Sub-SAWC/III/19/47, 27 October 1947, AIR 15/789.

AIR 20. Air Ministry, and Ministry of Defence: Air Historical Branch: Unregistered Papers.

'Anti-Submarine Problems of the Future,' TASW.4666/47, P.W. Burnett, for DTASW, 16 August 1947, AIR 20/6381.

'Defence of Ocean Convoys against Submarine Attack,' DTASW, TASW.397/48, August 1948, AIR 20/6384.

'The Problem Confronting Enemy Submarines,' TASW.396/48, August 1948, AIR 20/6384.

'Joint Sea/Air Warfare Committee: Minutes of the 2 meeting of the Committee held at the Admiralty on 27 August 1946,' SAWC 2/46(12), 27 August 1946, AIR 20/6842.

'Joint Sea/Air Warfare Committee: Report by the Joint Secretaries of the Joint Sea/Air Warfare Sub-Committees on the work carried out since 28 June 1949,' SAWC/I/50/2, 21 July 1950, AIR 20/6842.

'Minutes of the Seventh Meeting of the Policy and Plans Sub-Committee held in the Admiralty on 7 November 1947, Sub-SAWC 1/14/47, 13 November 1947, AIR 20/10176.

AIR 40. Directorate of Intelligence Files.

'Report on anti-convoy activity by Kptlt. Topp (U-boat tactics by a German Commander),' 1942, AIR 40/1821.

AIR 41. Air Historical Branch: Narratives and Monographs.

'The RAF in Maritime War, Vol. IV: The Atlantic and Home Waters, The Offensive Phase, February 1943 – May 1944,' (First Draft) n.d., AIR 41/48.

'The RAF in Maritime War, Vol. V: The Atlantic and Home Waters, The Victorious Phase, June 1944 – May 1945,' Air Historical Branch (1), Air Ministry, n.d., AIR 41/74.

AIR 65. Air/Sea Warfare Development Unit: Reports.

' "High Tea" Range Tests with a Fast Submarine,' ASWDU Report No. 45/16, 25 May 1945, AIR 65/175.

CAB 81. Chiefs of Staff Sub-Committees, 1939-1945.

'Russia's Strategic Interests and Intentions,' Report by the Joint Intelligence Sub-Committee, JIC(46)1(0) Final (Revise), 1 March 1946, CAB 81/132.

'Certain Assumptions for Planning Purposes,' Report by the Joint Intelligence Sub-Committee, JIC(46)19(0)(Final), 6 March 1946, CAB 81/132.

CAB 86. Battle of the Atlantic Committee, 1941-42 and Anti-U-Boat Warfare Committee, 1942-45.

'Minutes of Meeting, 12 January 1944,' in, 'War Cabinet, Anti-U-Boat Warfare Committee Meetings and Memoranda,' 1944, CAB 86/6.

'Minutes of the Meeting held at 10, Downing Street, SW1 on Tuesday, 31 October, 1944, at 6.0 pm,' AU(44) 3rd Meeting, War Cabinet Anti-U-boat Warfare, CAB 86/6.

'Minutes of the Meeting,' 26 January 1945, CAB 86/7.

CAB 120. Cabinet Office: Minister of Defence Secretariat: Records.

'Operation "Unthinkable", Report by the Joint Planning Staff,' G. Grantham, G.S. Thompson, W.L. Dawson, Offices of the War Cabinet, Final, 22 May 1945, CAB 120/691.

CAB 158. Ministry of Defence. Joint Intelligence Sub-Committee later Committee. Memoranda (JIC Series).

'Soviet Interests, Intentions and Capabilities – General,' Report by the Joint Intelligence Sub-Committee, JIC(47)7(Final), 6 August 1947, CAB 158/1.

'Scale and Nature of Attack against Sea Communications,' Joint Intelligence Committee, JIC(48)69(0)Final, 11 August 1948, CAB 158/4.

DEFE 2. Combined Operations Headquarters, and Ministry of Defence, Combined Operations Headquarters later Amphibious Warfare Headquarters: Records.

Minute, G.N. Oliver, 8 December 1947, ADM 1/21546; Minute, D of P, 17 December 1947, ADM 1/21546; 'Small Battle Units,' DTASW, TASW.4037/48, April 1948, DEFE 2/1660.

'SO Action against Enemy ["Walter" Type] Submarines,' SAWP2, 20 April 1948, DEFE 2/1660.

DEFE 3. Intelligence from Enemy Radio Communications, 1941-1945.

ZIP/ZTPGU/3082, TOI 1155, 30 August 1944, DEFE 3/735.

DEFE 5. Chiefs of Staff Committee Memoranda.

'Appreciation of Russian Intentions: Memorandum by the First Sea Lord,' Fraser [?], COS(49)161, 5 May 1949, DEFE 5/14.

'Research and Development Priorities: Report by the Defence Research Policy Committee,' H.T. Tizard, COS(49)220, 9 July 1949, DEFE 5/14.

DEFE 6. Joint Planning Committee.

'Plan "Galloper",' Chiefs of Staff Committee, Joint Planning Staff, JP(49)134(Final), 1 March 1950, DEFE 6/11.

'Strategic Guidance from the Standing Group to the Regional Planning Groups on the North Atlantic Treaty Organisation,' Chiefs of Staff Committee, Joint Planning Staff, JP(49)149(Final), 21 November 1949, DEFE 6/11.

DEFE 9. Ministry of Defence: Papers of Sir Henry Tizard, Chairman of Defence Research Policy Committee.

Note by Sir Henry Tizard to the Minister [of Supply], 24 August 1948, DEFE 9/12.

HW 1. Government Code and Cypher School: Signals Intelligence Passed to the Prime Minister, Messages and Correspondence.

'Naval Headlines, No. 1150,' Naval Section, 27 August 1944, HW 1/3191.

PREM 3. Prime Minister's Papers.

'Remarks on Air Staff Paper on the Employment of Heavy Bomber Force against Enemy U-boat Organisation.' [covered by First Lord's note, 15 December 1944], PREM 3/414/1.

'A Forecast of the Results of the U-boat Campaign during 1945, Memorandum by the First Sea Lord,' Admiral of the Fleet A.B. Cunningham, COS(45)14(0), 6 January 1945, PREM 3/414/1.

'Forecast of the U-boat Campaign of 1945, Memorandum by the First Lord of the Admiralty,' A.V. Alexander, AU(45)7, 20 January 1945, PREM 3/414/1.

WO 208. War Office: Directorate of Military Operations and Intelligence, and Directorate of Military Intelligence.

'USSR General Report,' CX Report, 10 October 1945, WO 208/4566.

<u>**NARA2 – National Archives and Records Administration 2, College Park, Maryland**</u>

RG 38. Records of the Office of the Chief of Naval Operations: Registered Publications Section: US Navy and Related Operational, Tactical & Instructional Publications, 1918-1970 and Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960.

'ATP1 [Allied Naval Maneuvering Instructions], Change 1: January 1952,' Box 4, RG 38, NARA2.

'Part IV – The Control and Operations of Aircraft and Surface Vessels in a CVE, April 1945,' in, 'Naval Air Anti-U-Boat Instructions (Short Title: NAUI's),' AWD 650/45, CB04405 (G.B.), Naval Air Warfare and Flying Training Division, April 1945, Box 147, RG 38, NARA2.

'Western Approaches Monthly News Bulletin, November 1944,' 18 December 1944, Box 396, RG 38, NARA2.

'Detection, Attacking, Hunting,' CB4097(2)(42), December 1942, Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 468, RG 38, NARA2

'Convoy A/S Escort,' in, 'Conduct of Anti-U-Boat Operations, 1940,' DASW, ASW.2191/40, CB4097(11)(42), November 1940 [with amendments to 25 April 1945], Box 468, RG 38, NARA2.

'Part 2 – Detection and Action (November 1944),' in, CB4097, 'Conduct of Anti-U-Boat Operations, 1940,' ASW.2191/40, DASW, November 1940 [with amendments to 25 April 1945], Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 468, RG 38, NARA2.

'A/S Searches and A/S Striking Forces,' DASW, CB4097(4), [1940], Records of the Office of the Chief of Naval Operations: Registered Publications Section, Foreign Navy and Related Foreign Military Publications, 1913-1960, Box 468, RG 38, NARA2.

'Detection, Attacking, Hunting,' CB4097(2)(41), December 1941, Box 468, RG 38, NARA2.

'Detection, Attacking, Hunting,' CB4097(2)(42), December 1942, Box 468, RG 38, NARA2.

'Conduct of Anti-U-Boat Operations – Part 2 – Detection and Action,' CB4097(2)(44), November 1944, Box 468, RG 38, NARA2.

'Conduct of Anti-U-Boat Operations – Part 10 – A/S Weapons,' DASW, CB4097(10)(44), July 1944, Box 468, RG 38, NARA2.

'Conduct of A/S Operations by Ships and Aircraft,' Admiralty and Air Ministry, CB04097(1/51) and SD 697(1/51), TASW.196/50, 3 October 1951, Box 468, RG 38, NARA2.

RG 313 Records of the Naval Operating Forces: Commander in Chief Atlantic (CinCLant) Secret Administrative Files, 1941-1949.

'Report of Coordinator of Undersea Warfare and Assistants' Visit to British Naval Activities, Jan. 19 – Feb. 12 1947,' Forrest Sherman, Deputy Chief of Naval Operations (Operations), Op-31B:ch (SC) A16-3(17) Serial 003P31, 30 April 1947, Box 90, RG 313, NARA2.

'Review of the Problems of Future A/S Warfare,' TASW.2014/47, [December 1946], in, 'Report of Coordinator of Undersea Warfare and Assistants' Visit to British Naval Activities, Jan. 19 – Feb. 12 1947,' Forrest Sherman, Deputy Chief of Naval Operations (Operations), Op-31B:ch (SC) A16-3(17) Serial 003P31, 30 April 1947, Box 90, RG 313, NARA2.

'Joint Paper on Sea and Air Aspects of Search and Convoy Defence,' P.W. Burnett, for DTASW, and F.J. Finnigan, Director of Operations, Sub-SAWC/II C.30414/D of Ops, [July 1946], Box 96, RG 313, NARA2.

'Possible Lines of Development of Submarine Tactics,' TASW.816/46, 'Appendix "A" to "Joint Paper on...Convoy Defence",' P.W. Burnett, for DTASW, and F.J. Finnigan, Director of Operations, Sub-SAWC/II C.30414/D of Ops, [July 1946], Box 96, RG 313, NARA2.

'General Implications of Improved Submarine Performance,' Section II, 'Joint Paper on...Convoy Defence,' Box 96, RG 313, NARA2.

'Preliminary Report of Exercises with USS *Trumpetfish*,' Captain E.A. Gibbs, RN, Captain (D), Fourth Escort Flotilla, No. D: 12/027/36, 11 June 1948, Enclosure A to 'USS *Trumpetfish* (SS425), Operations with Royal Navy Forces off Londonderry, May-June 1948,' James Fife, Commander Submarine Force, US Atlantic Fleet, FF13-8/A4-3, 22 July 1948, Records of the Naval Operating Forces: Commander in Chief Atlantic (CinCLant) Secret Administrative Files, 1941-1949, Box 96, RG 313, NARA2.

'Fifth Partial Report (Part I) on Project Op/V32/A16-3(17)(Revised): Development of Air and Coordinated Surface Tactics for use Against the Medium Speed Deep-Diving Submarines (Hunter-Killer Groups),' R.P. Biscoe, Commander Operational Development Force, 30 June 1948, Box 96, RG 313, NARA2.

'Defence of Fleet Units against Submarine Attack,' Sub-SAWC/II/64/48, September 1948, in 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

'The Tactical Employment of Patrol Groups,' Sub-SAWC/II/63/48, 8 September 1948, in 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

'A/S Tactical Instructions for Ships and Aircraft,' Sub-SAWC/II/66/48, 14 September 1948, in 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

'Maritime Radar for Search and Shadowing,' Sub-SAWC/II/62/48, n.d., in, 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

'Joint Sea/Air Warfare Committee: Minutes of the Seventeenth Meeting of the Tactical and Training Sub-Committee held in the Air Ministry on Friday, 15th October 1948,' Sub-SAWC/II/71/48, 13 October 1948, in 'Great Britain – Navy Anti-Submarine Warfare Doctrine,' Commander F.A. Brock, USN, Undersea Warfare Section, CinCNELM, 1 November 1948, Box 96, RG 313, NARA2.

'Summary of Operations Aircraft Development Squadron Four Detachment in the United Kingdom during the Period 26 May to 17 June 1948,' F.E. Bardwell, Commanding Officer, Aircraft Development Squadron Four, to Chief of Naval Operations, VX-4/A4-3 Serial: 005, 1 September 1948, Box 97, RG 313, NARA2.

'Proposed Evaluation of Present Guppy Submarine Conversion and Equipment,' L.R. Daspit, Commander Submarine Squadron Four, to Commander Submarine Force, US Atlantic Fleet, FC5-4/S1, 24 March 1948, Box 98, RG 313, NARA2.

'The Outline of Exercise "Trident",' in, 'Invitation to British Exercise "Trident" First Session,' A.W. Radford, Vice Chief of Naval Operations, Op-03/frb (SC) A4-3 Serial: 008P03, January 1949, Box 100, RG 313, NARA2.

'Third A/S Tactical Liaison Meeting held in HMS *Vernon* on 1 and 2 May 1947,' A.198/3/47, 17 May 1947, distributed by Op-32-F-45, n.d., Box 102, RG 313, NARA2.

'Trade Protection – Defence of Ocean Convoys,' Group Captain W.E. Oulton, Director (RAF) and Captain R.G. Onslow, Director (RN), Joint A/S School, Londonderry, No. 73/JAS/RAF/S.100/AIR, 17 October 1947, Box 102, RG 313, NARA2.

'Trade Protection – Defence of Ocean Convoys (73/JAS/RAF/S.100/AIR), Wing Commander C.B. Gavin-Robinson, RAF, and Commander J.W. Hale, RN, Sub.SAWC/II/36/48, 18 February 1948, Box 102, RG 313, NARA2.

'Trade Protection – Defence of Ocean Convoys,' Group Captain W.E. Oulton, Director (RAF) and Captain R.G. Onslow, Director (RN), Joint A/S School, Londonderry, No. 725, 25 February 1948, Box 102, RG 313, NARA2.

'The Defence of Ocean Convoys against Submarine Attack, TASW.397/48,' in 'Anti-Submarine Warfare,' Memorandum for Chief of Naval Intelligence, File: A16-3, Serial: 00926, 1 October 1948, Box 102, RG 313, NARA2.

'Composition of Hunter-Killer Groups,' W.R. Edsall, Assistant Chief of Staff to Commander in Chief US Atlantic Fleet, FF13/A4-3(00189), 14 December 1949, Box 103, RG 313, NARA2.

'Memorandum for the File,' 28 November 1944, Enclosure (S) to 'High Speed Submarines – Report of Tests Against (Project No. 103),' T.A. Turner Commander Anti-Submarine Development Detachment, United States Atlantic Fleet, ASDD/A5-7 Serial: 0024, 6 April 1945, Box 4476, RG 313, NARA2.

NAC – National Archives of Canada, Ottawa

RG 24. A/S Warfare Files.

'An Outline of the Conduct of Naval Air A/S Operations in Defence of Trade,' Acting Commander A.W.F. Sutton, RN, Joint A/S School, Londonderry, 15 September 1947, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

'Joint A/S Warfare – Convoy Defence and Offensive Operations – A General Outline Lecture,' Lieutenant Commander D.E.B. Field, RN, Wing Commander H.A.S. Disney, RAF, Commander A.W.F. Sutton, RN, Joint A/S School, Londonderry, Issued 28 May 1947, Revised 27 October 1947, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

'Précis: Command and Control of Joint A/S Operations,' Wing Commander H.A.S. Disney, RAF, n.d., File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

'RAF Staff College: Précis of Lecture on Surface Tactics,' Lieutenant Commander D.E.B. Field, RN, Joint A/S School, Londonderry, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

'Joint A/S School Exercises,' The Commanding Officer, 19Carrier Air Group to The Commanding Officer, HMCS *Magnificent*, 28 May 1948, File S-4973-30 Vol. 1, Vol. 1814, Acc. 83-84/167, RG 24, NAC.

'Anti-Submarine Tactical Papers,' Naval Secretary, Naval Service, Department of National Defence, NSS 8100-5 (Staff), 3 February 1949, File 8100.5, Vol. 3734, RG 24, NAC.

'Fourth Anti-Submarine Conference,' J.D. Price, Vice Chief of Naval Operations, OP 312F/rh A19 Serial 00296P31, 18 August 1949, File 8100.5, Vol. 3734, RG 24, NAC.

'Anti-Submarine Tactics and Training,' Squadron Leader R.J. Wilcock, RCAF, for Air Member, Canadian Joint Staff, London, S25-28 (Armament), 3 April 1951, File S-28-1-4, Vol. 5270, RG 24, NAC.

'Test of MAD Equipment for Detecting the Presence of Submerged Submarines from the Air,' Coastal Command Development Unit, RAF Tain, Ross-shire, Report No. 87, CCDU/20/122/AIR, 3 December 1942, File S-28-1-4, Vol. 5271, RG 24, NAC.

'Minutes of the First Meeting of DASW's Sub-Committee of ACNS(UT)'s U-boat Warfare Committee held at the Admiralty on Thursday, 30 November 1944, (Copy)' Folder NSS 1271-22, Vol. 8080, RG 24, NAC.

'Minutes of the 65th Meeting of the U-Boat Warfare Committee Held at the Admiralty on Thursday 10th May 1945,' 12 May 1945, Folder NSS 1271-35, Vol. 1, Vol. 8080, RG 24, NAC.

'Anti-Submarine Measures,' E.J. King, Commander in Chief, United States Fleet and Chief of Naval Operations, FF1/A16-3(9), 19 May 1943, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

'Submarine Warfare in the Channel,' Commander J.D. Prentice, RCN, Senior Officer EG11, HMCS *Ottawa*, to Commodore (D), Western Approaches, 17 July 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

Admiralty Message to AIG #2 359AZ, Repeated to Commander 12th Fleet, 26 August 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

'Tactics against Fast Submerged U-Boats,' A/Commander J. Plomer, RCNVR, Director of the Combined Tactical Unit to Captain (D), Halifax, 25 November 1944, Folder CNA 7-6-1, Vol. 11022, RG 24, NAC.

'Submarine Warfare in the Pacific,' Secretary, Naval Board, NSS. 11270-53 Vol. 1 (Staff), 13 June 1945, Folder CNA 7-5-9, Vol. 11022, RG 24, NAC.

'Hints for Escort Work,' Admiral Max Horton, Commander-in-Chief, Western Approaches, WA0760/136, 4 May 1943, Folder CNA 7-6-5, Vol. 11023, RG 24, NAC.

'Hints on Escort Work – Part III,' A/Captain J.D. Prentice, RCN, Captain (D) Halifax, Memorandum D.0-24-11, 21 May 1943, Folder CNA 7-6-5, Vol. 11023, RG 24, NAC.

'Periodic Summary of the Anti-U-Boat Campaign, No. 37 – 4 December 1943,' Captain C.D. Howard-Johnston, DAUD, 6 December 1943, File D 01-18-0, Vol. 11575, RG 24, NAC.

Minute, Commodore G.W.G. Simpson, RN, Commodore (D), Western Approaches, No.DW.40/603.OP, 26 July 1944, File D 01-18-0, Vol. 11575, RG 24, NAC.

'Western Approaches Tactical Policy,' Admiral Max Horton, Commander-in-Chief, Western Approaches, No. WA.0609/45, 27 April 1943, File 307-0, Vol. 11940, RG 24, NAC.

National Archives of Australia, Melbourne

MP1049/5

'Item 6 – The Anti-Submarine Problem,' Captain R.G. Onslow, DSO, RN, Naval Director of the Joint Anti-Submarine School, in 'Minutes of Naval Air Tactical Conference held at RNB, Lee-on-Solent, 31 May to 3 June 1948,' AWD.394/48, n.d., NAA(M): MP1049/5, 1874/2/63.

'Admiralty Research Laboratory and Admiralty Gunnery Establishment, Teddington: Statement of Work in Hand – August 1945,' NAA(M): MP1049/5, 1968/2/577.

'Underwater Detection Establishment – Research and Development – Progress Report Number 2,' DTSR, 17 November 1947, NAA(M): MP1049/5, 1968/2/663.

'Underwater Weapons and Equipment – Research Reports – Summary,' DTSR, 28 April 1949, NAA(M): MP1049/5, 1968/2/780.

'Underwater Weapons and Equipment Research Reports,' H. Newcomb, DNL, 5 May 1949, NAA(M): MP1049/5, 1968/2/780.

'HMUDE Progress and Projects Bi-Annual Meeting,' I.K. Purvis, for DTSR, 2 September 1949, NAA(M): MP1049/5, 1968/2/780.

'HMUDE Summary of Progress,' 1 December 1948, NAA(M): MP1049/5, 1968/2/800.

'HMUDE Summary of Progress,' 1 December 1949, NAA(M): MP1049/5, 1968/2/800.

'Anti-Submarine Protection of Convoys,' A/Commander Harvey Newcomb, A/S 121/1/3, 5 May 1943, NAA(M): MP1049/5, 2026/12/537.

MP1049/6

'Report on 10 TAS Liaison Meeting – HMS *Vernon* – 18-20 September 1951,' Lieutenant Commander M.S. Batterham, RANVR, 9 October 1951, NAA(M): MP1049/6, 5036/32/140.

MP1185/8

'First Commonwealth TAS Liaison Meeting [10-20 October 1949] – Report by RAN Representative,' Lieutenant Commander I.K. Purvis, RAN, n.d., NAA(M), MP 1185/8, 1846/4/343.

'Creeping Attack,' Admiralty Message, DTG 181904A August 1943, NAA(M): MP1185/8, 1932/3/45.

'Reports on Creeping Attacks,' Admiral Max Horton, Commander-in-Chief, Western Approaches, WA2695/0770/64, 8 September 1944, NAA(M): MP1185/8, 1932/3/45.

'U-Boat Tactics,' Secretary, Navy Board, Melbourne, 22 September 1944, NAA(M): MP1185/8, 1932/3/45.

'Inshore U-Boat Operation,' Admiralty Message, CASO No. 6, DTG 252307A October 1944, NAA(M): MP1185/8, 1932/3/45.

'Convoy Protection in Inshore Waters,' Admiralty Message, CASO No. 7, DTG 131737Z February 1945, NAA(M): MP1185/8, 1932/3/45.

'Use of Squid-Fitted Ships,' Admiralty Message, CASO No. 8, DTG 271656Z April 1945, NAA(M): MP1185/8, 1932/3/45.

AWM – Australian War Memorial, Canberra

'Report on Development in A/S Tactics in the United Kingdom, June 1944,' AWM 54, 81/4/81.

'Schnorkel,' Appendix "A" to 'Report on German and Our Strategy and Tactics: Anti-Submarine Warfare (Section C, Sub-Sections 1-4),' Wing Commander T.V. Stokes, RAAF, Overseas Headquarters, London, 61/50/Air, 14 November 1944, AWM 54, 81/4/81.

'Minutes of Squadron Commanders' Conference held at Headquarters, Costal Command on 29 November 1944,' AWM 54, 81/4/81.

Wing Commander T.V. Stokes, RAAF Overseas Headquarters, to Group Captain Garing, CBE, DFC, DSC, Director of Operational Requirements, Canberra, 27 December 1944, AWM 54, 81/4/81.

'Detection of Schnorkel Fitted U-Boats,' Headquarters, Coastal Command, CC/S.17261 A/U Ops., 17 December 1944, AWM 54, 81/4/81.

'Section C. Anti-Submarine, Sub-Section 3, Enemy Tactics: Further Information on Schnorkel,' Wing Commander T.V. Stokes, RAAF, Overseas Headquarters, 11 January 1945, AWM 54, 81/4/81.

'Visual Sighting of U-Boats,' Wing Commander T.V. Stokes, RAAF, Overseas Headquarters, 12 December 1944, Australian War Memorial, Canberra, AWM 54, 81/4/81.

'Outline of Coastal Command's Anti-U-Boat Warfare 1939-August 1944,' Wing Commander T.V. Stokes, [20 September 1944], Australian War Memorial, Canberra, AWM 54, 81/4/81.

IWM –Imperial War Museum, London

P.G. Cazalet Papers

'Report of Proceedings, Convoys JW.65 and RA.65,' Captain (D), Twenty Third Destroyer Flotilla, 30 March 1945, File PGC 3(b), IWM P432.

'Second Support Group Orders,' Captain F.J. Walker, CB, DSO, 19 June 1943 (still extant, with amendments, 9 March 1944), File PGC 5, IWM P432.

D. Coyne Papers

Memoir, Mrs D. Coyne, [early 1990s], IWM 93/22/1.

M.J. Evans Papers

'Reports of Proceedings – Convoys ONS18 and ON202,' Admiral Max Horton, Commander-in-Chief, Western Approaches, 31 December 1943, Captain M.J. Evans, RN, Papers, IWM 65/25/1.

I.L.M. McGeoch Papers

'The Offensive Value of the Modern Submarine,' "Salvo" (Lieutenant I.L.M. McGeoch), May 1939, IWM P347.

J.P. Mosse Papers

John Mosse, 'Half a Lifetime,' Part II, August 1986, IWM 90/23/1.

G.H. Roberts Papers

'Life and Letters of Gilbert Howland Roberts,' Book 1, '11 October 1900 - 4 August 1945' [c. mid-60s], Captain RN, Papers, IWM 66/28/1.

CCAC – Churchill College Archives Centre, Cambridge

GOEV – Goodeve Papers

A.B. Wood, OBE, DSc, 'From Board of Invention and Research to Royal Naval Scientific Service,' in, *Journal of the Naval Scientific Service*, Vol. 20, No. 4 (July 1965), pp. 16-97, CCAC, GOEV 3/7.

'Example C: The Spit Beam Asdic,' Draft, n.d., CCAC, GOEV 3/1.

KEYN – Keynes Papers

Unmarked Paper of Detailed Comments on Problems at HMA/SEE, [August 1942], 'Papers Re Resignation from HMA/SEE, Fairlie in 1942,' KEYN 1, Correspondence: World War II and Radar, Acc. 23/667/669 (Keynes), Box 1, CCAC, KEYN.

FWCT – Fawcett Papers

'Possibilities of the R5 Helicopter,' 10 January 1944, CCAC, FWCT 2/4/5.

'Note on Depth Charge Attacks by Aircraft,' [L. Solomon], CAOR, 17 February 1944, CCAC, FWCT 2/4/5.

'The U-boat War Through German Eyes' (Most Secret) by Fawcett AUD, 6 March 1944, CCAC, FWCT 2/4/5.

'Possibilities of the Coming U-boat Offensive [April 1945],' H.W. Fawcett, Naval Staff, Coastal Command, 1 December 1944, CCAC, FWCT 2/4/5.

Howard-Johnston, DAUD, to Fawcett, SNLO Coastal Command, Ref. D.327, 26 December 1944, CCAC, FWCT 2/4/5.

HWJN – Howard-Johnston Papers

C.D. Howard-Johnston to J.D. Brown, NHB, 24 February 1980, CCAC, HWJN.

NMM(G) – National Maritime Museum, Greenwich

Gretton Papers

(Since these papers were used, they have been catalogued.)

'Bergen,' in, 'Report on Interrogation of German Naval Staff Officers of the U-Boat Arm at Flensburg and Bergen,' Group Captain Gates, CC/s.17384 A/U Ops., 6 June 1945, Gretton Papers, MSS/93/008, NMM(G).

'Interrogation at Flensburg,' in, 'Report on Interrogation of German Naval Staff Officers of the U-Boat Arm at Flensburg and Bergen,' Group Captain Gates, CC/s.17384 A/U Ops., 6 June 1945, Gretton Papers, MSS/93/008, Section S9, NMM(G).

Gretton to Howard-Johnston, 15 September 1980, 'H-J' File, Gretton Papers, MSS/93/008, NMM(G).

Howard-Johnston to Gretton, n.d. [1981], 'H-J' File, Gretton Papers, MSS/93/008, NMM(G).

Baker-Cresswell to Gretton, 5 October 1981, 'Battle of the Atlantic,' Gretton, 23 Part 1, 1 of 2, MS93/008, NMM(G).

NMM(W) – National Maritime Museum, Woolwich

Ships' Cover 746/A, Super-*Seraph* (*Scotsman*), Folio 4, NMM(W).

Certificate 'P.012938 1944' from Admiral Superintendent, Devonport Dockyard, 24 November 1944, Ship's Book, '*Seraph* – Late – *P.219*,' NMM(W).

RNM – Royal Naval Museum, Portsmouth

Commander A.F.C. Layard, Diary, 7 October 1944, RNM.

Commander A.F.C. Layard, Diary, 3-6 February 1945, RNM.

NHB – Naval Historical Branch, Ministry of Defence

CB917

'Home Waters – Part VIII, December 1916 to April 1917,' DTSD, Naval Staff Monographs (Historical) – Volume XVIII, Monograph No. 34, CB917Q, [OU 5528(G)], May 1933, NHB.

'Home Waters – Part IX, 1 May 1917 to 31 July 1917,' DTSD, Naval Staff Monographs (Historical) – Volume XIX, Monograph No. 35, CB917R, [OU 5528(H)], August 1939, NHB.

CB1515

'The Atlantic Convoy System, 1917-1918,' Captain H.E. Manisty, RN, (Director of Convoys 1917), CB1515(14), (Short Title: TH14), Technical History Section, Admiralty, October 1919, NHB.

CB3044

'Manual of Anti-Submarine Warfare, 1939,' Tactical Division, CB3044, February 1939, NHB.

CB3301

'Home Waters and the Atlantic, Volume I, September 1939 – 8 April 1940,' Naval Staff History, Second World War, CB3301(1), 31 December 1954, NHB.

CB3307

'The Development of British Naval Aviation, 1919-1945,' Naval Staff History, Second World War, Vol. I, CB3307(1), BR1936(53)(1), 14 July 1954, NHB.

CB04050

'Monthly Anti-Submarine Report, October 1939,' Naval Intelligence Division, NID.3141/39, CB04050/39(10), n.d., NHB.

'The Tactical Problem of the U-boat,' in 'Monthly Anti-Submarine Report, November 1940,' DASW, CB04050/40(11), [December 1940], NHB.

'Instructions for Convoy Escorts,' in 'Monthly Anti-Submarine Report, December 1940,' DASW, CB04050/40(12), [January 1941], NHB.

'U-boat Tactics,' in, 'Monthly Anti-Submarine Report, January 1941,' DASW, CB04050/41(1), [February 1941], NHB.

'Report of Committee on the Winter Campaign of 1941-1942 in the Battle of the Atlantic,' in, 'Monthly Anti-Submarine Report, April 1941,' DASW, CB04050/41(4), [May 1941], NHB.

'Monthly Anti-Submarine Report, November 1942,' DASW, CB04050/42(11), [December 1942], NHB.

'Monthly Anti-Submarine Report, February 1944,' DAUD, CB04050/44(2), 15 March 1944, NHB.

'Monthly Anti-Submarine Report, May 1944,' DAUD, CB04050/44(5), 15 June 1944, NHB.

'Monthly Anti-Submarine Report, June 1944,' DAUD, CB04050/44(6), 15 July 1944, NHB.

'A Model Anti-U-Boat Operation in the Indian Ocean – 5-14 August 1944,' Section 6, 'Monthly Anti-Submarine Report, July 1944,' DAUD, CB04050/44(7), 15 August 1944, NHB.

'Monthly Anti-Submarine Report, October 1944,' DAUD, CB04050/44(10), 15 November 1944, NHB.

'Pack Tactics by Submarines of the United States Navy,' Section 5, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB.

'Enemy Anti-Asdic Tactics,' Section 5, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB.

'Asdic Trough the Ages,' Section 6, 'Monthly Anti-Submarine Report, January 1945,' Anti-U-Boat Division, CB04050/45(1), 15 February 1945, NHB.

'Classification of Contacts on the Bottom,' in, 'Monthly Anti-Submarine Report, April and May 1945,' DTASW, CB04050/45(4)&(5), 20 May 1945, NHB.

'Grand Admiral Dönitz on the U-boat War,' in, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB.

'Considerations Regarding the Operation of Type XXI, Précis of Text,' Grand Admiral Dönitz, [10 July 1944], Section III, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB.

'Choice of Weapons for "Opening-Up" U-boats,' Section V, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB.

'History of the "Gnat" Campaign,' Section IV, 'The Anti-Submarine Report, September, October, November and December 1945,' DTASW, CB04050/45(7), 19 December 1945, NHB.

CB04051

'*U-35*, Interrogation of Crew,' NID 01472/39, CB04051(6), [BR1907(103)], December 1939, NHB.

CB4097

'A/S Screening,' Part 3, 'Conduct of Anti-U-Boat Operations,' CB4097(3)(44), June 1944, NHB.

'Air and Surface A/S Searches and Striking Forces,' Part 4, BR1679(4) [formerly CB4097(4)(44)], June 1944, NHB.

'Information on U-Boats,' Part 13, 'Conduct of Anti-U-Boat Operations,' CB4097(13)(44), June 1944, NHB.

CB4127

'Asdic Operating and Control: Echo Operating Procedure,' A/SW.1031/44, CB4127(2)(45), July 1945, NHB.

'Asdic Operating and Control: Supplementary Notes on Procedure and Control,' ASW 304/45, CB4127(4)(45), July 1945, NHB

CB04234

'Admiralty Convoy Instructions to Escorts: General – Operation of Surface Escorts,' Anti-U-Boat Division, CB04234(2)(44), August 1944, NHB.

Foreign Documents Section (FDS)

'25 June 1944,' in, 'Translation of PG/30349, BdU's War Log, 16-30 June 1944,' FDS, NHB.

'*Kriegstagebuch*, *U-247*, 18 May to 28 July 1944' NID, PG/30225/NID, FDS, NHB.

'Summary of Statements made by German Naval and Technical Personnel,' NID 1/PW, Summary No. 133 for week ending 22 June 1945, 'P/W Summaries, 121-136' Vol. VII, FDS, NHB.

'Preliminary Description and Operating Instructions for the U-boat "Schnorchel" Installation, (Short Title: TR/P/5758/NID),' Reg. No. P/5758/NID, 21 October 1944, Box 266, FDS, NHB.

Minute, Clive Loehnis, DNI to Admiral (Submarines), DASW, DAUD and E-in-C, 29 October 1944, Box 266, FDS, NHB.

'Schnorchel, Secret File, Commandant, Section E, No. 7/44,' PAL/G/247, TR/P/16437/NID, n.d., Box 266, FDS, NHB.

'Translation of German Document "Überlegung Z. Einsatz Des Typ XXI", Considerations Regarding the Operation of Type XXI,' Clive Loehnis, DNI, TR/PG/18487/NID, NID 12A/NS/P/682, 24 July 1945, Box 269, FDS, NHB.

'Operation of U-boat Type XXI (Document issued by Admiral Dönitz from Naval Staff Headquarters on 10 July 1944),' Department of Research Programmes and Planning, Admiralty, ACSIL Translation No. 542 (PG.18487), March 1952, FDS, Box 269, NHB.

'*Kampfanweisungen fur Typ XXIII* (Battle Instructions for Type XXIII),' M.G. Saunders (tr.), DNI, NID.24, Ref: TR/PG/28986/NID, 24 April 1946, Box 270, FDS, NHB.

War Diaries

'Monday, 18 September 1939, War Diary (Naval), 22 August to 30 September 1939,' NHB.

'Tuesday, 24 September 1940, War Diary (Naval), 21-30 September 1940,' NHB.

'Tuesday, 11 July 1944, War Diary (Naval), 1-15 July 1944,' NHB.

'Admiralty, 021511B to C-in-C, WA...,' in, 'Saturday, 2 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'Admiralty, 021650B to C-in-C, WA,' in, 'Saturday, 2 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'C-in-C, WA 031805B to Admiralty,' in, 'Sunday, 3 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'Sunday, 3 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'DAUD 081734B to C-in-C, WA,' in, 'Friday, 8 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'C-in-C, WA, 092030 WAGM(N)045N,' in, 'Saturday, 9 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'C-in-C, WA, 092035 to Admiralty,' in, 'Saturday, 9 September 1944, War Diary (Naval), 1-14 September 1944,' NHB.

'Monday, 7 May 1945, War Diary (Naval), 1-15 May 1945,' NHB.

Searches

'Anti-Submarine Measures in World War I,' Commander F. Barely, Historical Section, S.5659, Searches Vol. 29, 30 November 1960, NHB.

F. Barley and D.W. Waters Papers

'The Convoy System: "Offensive or Defensive"?' Commander F. Barley and Lieutenant Commander D.W. Waters, Historical Section, Admiralty, December 1954, NHB.

'A "New Look" at "Offence" and "Defence": The Anti-U-Boat Campaign, 1939-1945, A Brief Statement of Facts,' F. Barley and D.W. Waters, Historical Section, 15 October 1955, DWW24, Box PT134, NHB.

'[Battle of the Atlantic], Chapter III, Between the Wars,' [F. Barely and D.W. Waters], n.d., Box PT135, NHB.

'[Battle of the Atlantic], Chapter V, September 1939,' [F. Barely and D.W. Waters], n.d., Box PT135, NHB.

'Russian Submarines in the Second World War: An Estimate of their Efficiency (Reference: NATO (Secret) ID 0940/1 of 4 January 1955),' Historical Section, Admiralty, Box PT135, NHB.

U-boat Assessment Committee

'Record of Anti-Submarine Attacks: A. Attacks made during September 1939,' in, 'Record of Anti-Submarine Attacks, September 1939 to September 1940,' DASW, NHB.

'Record of Anti-Submarine Attacks: B. Attacks made during October, November and December 1939,' in, 'Record of Anti-Submarine Attacks, September 1939 to September 1940,' DASW, NHB.

'Assessment Committee Serial No. 319. Reference: ASW.1760/43,' from, 'Proceedings of U-Boat Assessment Committee, April–June 1943,' Vol. 11, NHB.

'Assessment Committee Serial No. 126. Reference: AUD.330/44,' from, 'Proceedings of U-Boat Assessment Committee, January–March 1944,' Vol. 14, NHB.

'Assessment Committee Serial No. 149. Reference: AUD.355/44,' from, 'Proceedings of U-Boat Assessment Committee, January–March 1944,' Vol. 14, NHB.

'Assessment Committee Serial No. 154. Reference: AUD.355/44,' from, 'Proceedings of U-Boat Assessment Committee, January–March 1944,' Vol. 14, NHB.

'Assessment Committee Serial No. 71. Reference: AUD.1110/44,' from, 'Proceedings of U-Boat Assessment Committee, July–September 1944,' Vol. 16, NHB.

'Assessment Committee Serial No. 63. Reference: AUD.201/45,' from, 'Proceedings of U-Boat Assessment Committee, October 1944 – April 1945,' Vol. 17, NHB.

'Assessment Committee Serial No. 31. Reference: AUD.078/44, AUD.1570/44,' from, 'Proceedings of U-Boat Assessment Committee, October 1944 – April 1945,' Vol. 17, NHB.

Naval War Memorandum (European)

'Protection British Shipping in the Vicinity of the British Isles during the first 14 days of an Emergency,' Captain F.R Garside, Assistant D of P, 30 August 1938, in, 'Naval War Memorandum (Germany),' Admiralty, 1937-1939, Case 00244, Vol. II, NHB.

'Review of the Requirements of Trade Protection,' Section III, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.

'Methods of Affording Protection,' Section III, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.

'Trade Protection – Detailed Arrangements,' Section VII, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.

'Movement of Advanced Air Striking Force and Field Force to France, Plan "W4",' Section IXA, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.

'Minesweeping and Anti-Submarine Arrangements,' Section XI, 'Naval War Memorandum (European),' Admiralty Letter, M.00697/39, January 1939, Case 00244, Vol. III, NHB.

Biographical Files

'Philip Currey,' Biography, July 1953, NHB.

Miscellaneous Files

'Anti-Submarine Operations in North Atlantic, 12 to 16 September 1939,' Pack No. 0556/0, BSR 522/1, NHB.

'Report of Proceedings between 11 September and 17 September 1939,' Vice Admiral L.V. Wells, CB, DSO, Vice Admiral, Aircraft Carriers, HMS *Ark Royal*, AC3, 17 September 1939, 'Anti-Submarine Operations in North Atlantic, 12 to 16 September 1939,' Pack No. 0556/0, BSR 522/1, NHB.

'Abstract 24, AHH,' TSD/Historical Section, Abstract Volume 24, A.H. Haggard, n.d., NHB.

'German U-boat Strategy in the War,' Appendix XVIII, to 'Some Weaknesses in German Strategy and Organisation, 1933-1945,' Report by the Joint Intelligence Sub-Committee, JIC(46)33(Final), 20 October 1946, NHB.

'German Underwater Rockets,' US Naval Technical Mission in Europe, Technical Report No. 500-45, October 1945, NHB.

'Historical Section of TSD – Review of Narrator Posts, Roger M. Bellairs, 11 November 1949, T.27309, NHB.

'CAFO 312 – Submarines – Nomenclature,' TSD.61/47, 26 September 1947, NHB.

'Daily Positions of U-boats, 15 January 1945 to 15 May 1945 (excluding Arctic Waters),' Captain Peyton-Ward, 14 March 1957, NHB.

'Staff Meeting held in the Upper War Room on 13 September at 1030 am,' in, 'Staff Meetings in Upper War Room,' Vol. 14, 1 September to 31 December 1944, NHB.

'*U-448* and *U-550*, Interrogation of Survivors,' June 1944, "U-448 and U-550", NHB.

Staff Histories

'Arctic Convoys, 1941-1945,' Naval Staff History, Battle Summary No. 22, Historical Section, Admiralty, 1954, NHB.

Commander G.A. Titterton, Historical Section, Admiralty, to Squadron Leader Mervyn Mills, AHB, Air Ministry, 29 March 1959, in, 'Selected Convoys: Mediterranean, 1941-42, Revised Battle Summaries, Nos. 18, 32,' Folder, NHB.

'The Battle of the Atlantic,' Lieutenant Commander R.J. Goodman, RNVR, Lieutenant Commander K.W. McMahan, USNR, Lieutenant E.J. Carpenter, USNR, and Lieutenant Commander L.A. Griffiths, RNVR (ed.), GC&CS Naval History, Vol. XVIII, c. December 1945, NHB.

'The German Navy – The U-Boat Arm,' Lieutenant H.M. Anderson, RNVR, Lieutenant Commander R.J. Goodman, RNVR, and Commander A.M.S. MacKenzie, RNVR (ed.), GC&CS Naval History, Vol. XVII, c. December 1945, NHB.

5th Escort Group Narrative

'5th Escort Group Narrative: 2 September 1944 – 20 January 1945,' NHB.

'5th Escort Group Narrative: 21 January – 12 March 1945,' NHB.

AL – Admiralty Library, Ministry of Defence

CB0259

'Remarks on Submarine Warfare,' Operations Division, CB0259, January 1917, AL.

CB620

'Remarks on Submarine Tactics against Convoys,' Anti-Submarine Division, Naval Staff, Admiralty, CB620, October 1917, in, 'Convoy Orders, 1917-1919,' AL.

CB648

'Remarks on Submarine Tactics against Convoys, Protection of a Convoy by Extended Patrols, Instructions for Escorts and Patrols, 1919,' Convoy Section Division, Naval Staff, CB648(2)A, 30 April 1919, in, 'Convoy Orders, 1917-1919,' AL.

CB680

'Remarks on Protection of a Convoy by Extended Patrols,' Anti-Submarine Division, Naval Staff, Admiralty, CB680, November 1917, in, 'Convoy Orders, 1917-1919,' AL.

CB1182

'German Navy (Submarines),' CB1182S, [NID], April 1918, AL.

'Tactics of Attack,' in Appendix I to 'German Navy (Submarines),' CB1182S, [NID], April 1918, AL.

'Procedure when Hunted with Hydrophones,' in Appendix II to 'German Navy (Submarines),' CB1182S, [NID], April 1918, AL.

CB1870

'Anti-Submarine Manual, Volume III, Part 1 – Text,' DASW, CB1870A(39) [BR1681(A)], October 1939, AL.

CB3016

'Progress in Tactics, 1930,' Tactical Division, CB3016/30 July 1931, AL.

'Progress in Tactics, 1931,' Tactical Division, CB3016/31 August 1932, AL.

'Progress in Tactics, 1932,' Tactical Division, CB3016/32 July 1933, AL.

'Progress in Tactics, 1934,' Tactical Division, CB3016/34 August 1934, AL.

'Progress in Tactics, 1935,' Tactical Division, CB3016/35 October 1935, AL.

'Progress in Tactics, 1937,' Tactical Division, CB3016/37 December 1937, AL.

'Progress in Tactics, 1937,' Tactical Division, CB3016/37, December 1937, AL.

'Progress in Tactics, 1938,' Tactical Division, CB3016/38 July 1938, AL.

'Progress in Tactics, 1939,' Tactical Division, CB3016/39 June 1939, AL.

Technical Histories

'The Anti-Submarine Division of the Naval Staff, December 1916 – November 1918,' Technical History No. 7 (TH7), CB1515(7), Technical History Section, Admiralty, July 1919, AL.

'Aircraft v. Submarine: Submarine Campaign, 1918,' Technical History Section, Admiralty, CB01515(4), The Technical History and Index: A Serial History of Technical Problems dealt with by Admiralty Departments, Vol. 1, Part 4, (TH 4), March 1919, AL.

Miscellaneous Files

DNI, to Admiralty Librarian, 10 June 1937, and, 'The Naval War, 1914-1918, Submarine War on Commerce' German Official History, Vol. III, Pt. 1, CH. 1-12, AL.

'The Evolution of the *Osprey*,' Lieutenant Commander F.M. Mason, Summer 1938 (issued 30 January 1942), P.1009, AL.

DHH – Directorate of History and Heritage, Ottawa

'US Fleet, Anti-Submarine and Escort of Convoy Instructions (BUSCIs),' FTP 223A, January 1945, File 79/532, DHH.

H.W. Smith, 'Countering the Fast Conventional Submarine, 1946-1956,' in 'Sonar Systems in the RCN, 1945-68,' Partial Draft, 15 January 1997, DHH.

'Description of Method Used by HMCS *Saint John* in Attacking Bottomed Contacts,' anon, n.d., D.Hist File "*Saint John*", DHH.

Marc Milner, 'The RCN and the Offensive Against the U-Boats,' unpublished monograph, June 1986, DHH.

DNH – Directorate of Naval History, Canberra

'Monthly Intelligence Report, July 1949,' NID, 10 August 1949, DHH.

NHC – Naval Historical Center, Navy Yard, Washington

Contemporary History Branch

'History of Patrol Bombing Squadron One Hundred Five (VPB-105),' Enclosure to Lieutenant Commander L.E. Harmon, USN, Commander Patrol Bombing Squadron One Hundred Five, FVPB-105/A12, Serial 015, 5 February 1945, NHC.

'Undersea Warfare and Maritime Strategy: The American Experience,' Michael A. Palmer, n.d., NHC

Operational Archives

'Proceedings of Anti-Submarine Warfare Conference, 17 June 1946,' Op-34H:jn (SC) A16-3(17) Serial: 00012P34, Forrest Sherman, Deputy Chief of Naval Operations, 25 June 1946, Microfiche F3642-1, Sheet 001, OA, NHC.

'Summary of Information and Decisions of Conference on Operational Tests to be Conducted on German Submarines; Held at Office of Commander Submarines, Atlantic Fleet, 31 August 1945', S8/(01259), 10 September 1945, [OA, NHC],

'ComSubLant to Conference on Operational Tests to be Conducted on German Submarines,' 10 September 1945, Series 3, File 5, Box 10, Subs/UWD, OA, NHC.

Commander Special Submarine Group to ComSubLant, 21 February 1946, Series 3, File 5, Box 11, Subs/UWD, OA, NHC.

'German Surrendered Submarine – *U-1406* (Walter Turbine),' RB Carney, Office of Chief of Naval Operations, Op-414-C31/Mk Serial 00152P414 (SC)SS/EF30, 26 March 1946, Submarine/Undersea Warfare Division, Series III, 'German *U-190* to German *U-1406*,' Box 11, OA, NHC.

'Submerged Performance Tests on German Type XXI Submarines', William E. Schevill and Allyn C, Vine, Woods Hole Oceanographic Institution, 17 March 1947, File 3, Submarine/Undersea Warfare Division, Series III, Box 12, OA, NHC.

'Special Submarine Group – Prospective Operations Schedule (Revised),' W. R. Laughton, The Commander Special Submarine Group, FC5-2/S8, 1 March 1946, File 1, Submarine/Undersea Warfare Division, Series III, Box 12, OA, NHC.

'Notes on the "Kurier" System,' Enclosure (A), in, ' "Kurier" System of U-boat Communication,' 7 July 1945, Report No. 187-45, NavTecMisEu, Series III, Letter Reports #180-45 thru #205-45, Box 14, OA, NHC.

'Tactical Planning for High Speed U-boats,' Captain Harry D. Hoffman, USN, US Naval Technical Mission in Europe: Report No. 287-45, File A9-16(3)(10/Hn), Serial 00284, 11 September 1945, NavTecMisEu, Technical Reports No. 268-45 – 289-45, Series IV, Box 30, OA, NHC.

'Rubber Covering of German Submarines Anti-Asdic (German code name "Alberich"),' 20 September 1945, Report No. 352-45, NavTecMisEu, Series IV, Technical Reports #351-45 thru #370-45, Box 35, OA, NHC.

'Proceedings of Anti-Submarine Warfare Conference, 17 June 1946,' Op-34H:jn (SC) A16-3(17) Serial: 00012P34, Forrest Sherman, Deputy Chief of Naval Operations, 25 June 1946, Post 1946 Command File, CNO Ser: Conferences, Anti-Submarine Warfare 1946-1948, Box 325A, OA, NHC.

'Top Secret Annex to Study of Undersea Warfare,' 22 April 1950, Command File, Post 1 Jan 46, CNO Studies 1950, Box 475, OA, NHC.

"German Type XXIII Submarine in World War II", Microfilms of the German Naval Archives and Related Records, 1922-1945, Box T-90, OA, NHC.

<u>DERA Defence Evaluation and Research Agency, Winfrith</u>

'The Asdic and its Associated Weapons,' W.E. Dawson, ER30, HM Underwater Detection Establishment, Portland, February 1947, DERA, AN.15971.

'Asdic Trials with HM S/M *Seraph* as Target,' J.A. Hakes, Research Note No. 53, HMA/SEE Fairlie, November 1944. DERA, AN 28144.

<u>RNSM – Royal Naval Submarine Museum, Gosport</u>

Miscellaneous Files

'Records of Warship Construction, 1939-1945. The History of DNC Department,' Written 1945-46. Approved for issue by DSDE, 1981,' RNSM Box 5.

A1944

'Seventh Submarine Flotilla – Monthly General Letter No. 12 – November 1944,' Captain (S/m), Seventh Submarine Flotilla to Admiral (Submarines), 30 November 1944, RNSM A1944/008.

'Third Submarine Flotilla Monthly General Letter No. 13 – December 1944,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), 4 January 1945, RNSM A1944/007.

'Third Submarine Flotilla Monthly General Letter – February 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), 11 March 1945, RNSM A1944/007.

'Third Submarine Flotilla Monthly General Letter – June 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), 4 July 1945, RNSM A1944/007.

'Third Submarine Flotilla Monthly General Letter – July 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), No. TSF.1230/3714, 8 August 1945, RNSM A1944/007.

'Third Submarine Flotilla Monthly General Letter – August 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), 6 September 1945, RNSM A1944/007.

'Third Submarine Flotilla Monthly General Letter – October 1945,' Captain (S/M), Third Submarine Flotilla, HMS *Forth*, to Admiral (Submarines), 3 November 1945, RNSM A1944/007.

A1946

'Third Submarine Flotilla Monthly General Letter – February 1946,' Captain W.J.W. Woods, Captain (S/M), Third Submarine Flotilla, HMS *Forth*, No. TSF.0163/A/13, 28 February 1946, RNSM A1946/001.

A1948

'Underwater Internal Combustion Propulsion – General Considerations,' n.d., RNSM A1948/009.

A1977

'HM Submarine *U-1407* – Trials,' 23 May 1947, RNSM A1977/043.

'HM Submarine *U-1407* – Trials. Minutes of Meeting held at Fort Blockhouse 1100, 20 May 1947,' Enclosure in Flag Officer, Submarines' letter No. 534/SM.505 dated 23 May 1947, RNSM A1977/043.

A1980

"Kalapani", '*Fait Accompli*,' Extract from Naval Review, Vol. XLVI, 1958, RNSM A1980/059.

A1983

'HMS *Meteorite*. Appendix I to Flag Officer, Submarines' Memorandum No. SM.4038/777 dated 1st March, 1949,' RNSM A1983/100.

A1990

'Submarine Development: Lecture given to Senior Officers' Technical Course on Tuesday 6 May 1947,' [A.J. Sims], RNSM A1990/083.

A1991

'The Trend of Submarine Design,' Lecture by RN Newton, RCNC, DNC Department, November 1945, RNSM A1991/058.

'Submerged Performance Tests on Type XXI U-Boats', Staff Officer (Anti-Submarine) to Director of Torpedo, Anti-Submarine and Mine Warfare, Admiralty, A/S 230-1, 14 April 1947, RNSM A1991/076.

'HMS *Scotsman*: Conversion to Fast A/S Target,' Section 27, DNC Department, October 1948, RNSM A1991/098.

'Super *Seraph* – Submerged Control Preliminary Report. Report No. 25/46,' Superintendent, Admiralty Experiment Works, Haslar, to DNC, 11 November 1946, RNSM A1991/098.

'HM Submarine *Scotsman* – First of Class Trials,' G. Bryant, DNC Department to Flag Officer (Submarines), [5] November [1948], RNSM A1991/104.

'*Scotsman* Trials,' G. Bryant to DNC, Memo dated 5 November 1948, RNSM A1991/104.

'HM Submarine *Scotsman*. Report of First of Class Trials,' Flag Officer S/M, Fort Blockhouse, n.d., RNSM A1991/104.

'HMS *Seraph* (*P.219*) First of Class Trials, September 1944,' Office of Admiral (S/M), RNSM A1991/250.

A1994

'HMS *Meteorite* Trials Report, 17 March to 30 April 1949,' RNSM /097.

LHCMA – Liddell Hart Centre for Military Archives, King's College, London

'History of 30 Assault Unit,' LHCMA.

'Semi-Annual Summary of US Naval Forces Eastern Atlantic and Mediterranean, 1 April 1948 – 1 September 1948,' Commander-in-Chief, US Naval Forces Eastern Atlantic and Mediterranean, to Secretary of the Navy, 14 October 1948, LHCMA, MF 868.

BRNC – Britannia Royal Naval College, Dartmouth

P.W. Burnett, Cadet Record Card, No. 1522, Britannia Royal Naval College, Dartmouth.

G.A.G. Ormsby, Cadet Record Card, No. 1682, Britannia Royal Naval College, Dartmouth.

Interviews, Correspondence, etc.

Commander Richard Compton-Hall, Interview, 26 February 2000.

Professor Sir William McCrea, FRS, Interview, 17 April 1998.

Professor R.D. Keynes, Interview, 30 July 1999.

Geoffrey Budd, Telephone Interviews, 23-26 March 2003.

Lieutenant Commander John Guest, RNVR, Telephone Interview, 14 May 2001.

Telephone Interview, Rear Admiral J.H. Adams, CB, LVO, 2 March 1999.

Vice Admiral Sir Arthur Hezlet, KBE, CB, DSO*, DSC, Telephone Interviews, 22 and 23 September 2000.

R. Compton-Hall to A. Hampshire, [c. 1998].

D.C.R. Webb, Letter, 6 August 1997.

D.C.R. Webb, Letter, 9 June 1998.

Paul Mallett, Letter, 7 July 1999.

Erich Topp, Letter, 7 July 1997.

Erich Topp, Letter, 17 August 1997.

Professor Westcott, Letter, 28 June 1998.

Flight Lieutenant Bell, Letter, 1 July 1998.

'Torpedo Mine Mk 24,' Bernard Stephens, 30 April 1998.

Peter Evans, e-mail, 22 December 1998.

Vice Admiral Sir Lancelot Bell Davies, KBE, e-mail, 6 January 2001.

Norman Friedman, e-mail, 17/05/02 16:26:11 GMT.

'Philosophical Ramblings,' Doug McLean, e-mail, 01/11/03 21:13:28 GMT

Richard Compton-Hall, e-mail 20/06/00 11:27:31.

Richard Compton-Hall, e-mail 20/06/00 16:07:15.

Unpublished Private Papers, etc.

Adams Papers (since lodged at Churchill College Archives Centre, Cambridge)

'TAS Warfare Springback,' Lieutenant Commander J.H. Adams, Royal Navy, Commanding Officer [HMS *Creole*], 1 June 1950, Adams Papers.

'The Three Asdic Beams,' in, 'The Development of A/S Warfare,' Instructional Tactical Lecture, HMS Vernon, 10 June 1948, Adams Papers.

'The Development of A/S Warfare,' Instructional Tactical Lecture, HMS Vernon, 10 June 1948, Adams Papers.

World Ship Society

David J. Lees, 'Report of Operation "Thankful",' German Naval Group, World Ship Society, 1 December 1991.

SOCA, *Submarine Old Comrades Association, Gatwick Archive*

'Operation "Deadlight": Report of Proceedings of Lisahally Section, HMS *Onslow*' 29 December 1945 – 7 January 1946,' NOIC Londonderry, File M/0376/46, 26 January 1946, SOCA, Gatwick Archive.

MLJ, *Author's Collection*

'A Study of the Philosophy and Conduct of Maritime War, 1815-1945,' D.W. Waters, Historical Section, Admiralty, February 1954, revised June 1957, MLJ.

'The Asdic Beam,' in 'Asdic Notebook,' M. Walford, MLJ.

'EG2: D-Day to VE,' Ron Curtis, June 1997, MLJ.

Secondary Sources

Theses

Richard H. Allen, 'The Attack-at-Source and the Development of the British X-Craft Midget Submarine, 1945-1958' (MA, London, King's College, 2000).

Tim Benbow, 'The Impact of Air Power on Navies: The United Kingdom, 1945-1957,' (DPhil, St. Anthony's College, 1999).

Michael Shawn Cafferky, 'Uncharted Waters: The Development of the Helicopter Carrying Destroyer in the Post-War Canadian Navy, 1943-1964' (PhD, Carleton University, Canada, 1996).

William James Crowe Jr., 'The Policy Roots of the Modern Royal Navy, 1946-1963' (PhD, Princeton University, 1965).

George Durnford Franklin, 'British Anti-Submarine Tactics, 1926-1940' (MPhil, University of Glasgow, June 2001).

William Glover, 'Officer Training and the Quest of Operational Efficiency in the Royal Canadian Navy, 1939-1945' (PhD, London, King's College, 1993).

M. Llewellyn-Jones, 'British Responses to the U-boat, Winter 1943 to Spring 1945' (MA, London, King's College, December 1997).

D.M. McLean, 'The Last Cruel Winter: The RCN Support Groups and the U-Boat Schnorkel Offensive' (MA, Royal Military College of Canada, March 1992).

John Simpson, 'Understanding weapon acquisition processes: a study of naval anti-submarine aircraft procurement in Britain, 1945-55' (PhD, University of Southampton, 1976).

Books

Air Ministry, *The Origins and Development of Operational Research in the Royal Air Force* (London: HMSO, 1963).

Air Ministry, Pamphlet No. 248: *The Rise and Fall of the German Air Force (1933 to 1945)* (Issued by the Air Ministry (A.C.A.S.[I]), 1948).

Chris Ashworth, *RAF Coastal Command, 1936-1969* (Sparkford: Patrick Stephens, 1992).

C.R. Attlee, *As it Happened: His Autobiography* (London: Heinemann, 1954).

K.C. Baff, *Maritime is Number Ten: The Sunderland Era* (Privately Published, 1983).

Arthur Banks, *Wings of the Dawning: The Battle for the Indian Ocean, 1939-1945* (Malvern Wells: Images, 1996).

Correlli Barnett, *Engage the Enemy More Closely: The Royal Navy in the Second World War* (London: W. W. Norton & Co., 1991), p. 854.

Clay Blair, *Silent Victory: The US Submarine War Against Japan* (New York, 1975).

D.K. Brown (ed.), *The Design and Construction of British Warships, 1939-1945. The Official Record: Submarines, Escorts and Coastal Forces* (London: Conway, 1996).

Alan Burn, *The Fighting Captain: Frederick John Walker and the Battle of the Atlantic* (London: Leo Cooper, 1993).

W.S. Chalmers, *Max Horton and the Western Approaches* (London: Hodder and Stoughton, 1954).

Julian Corbett, *Some Principles of Maritime Strategy* (Naval Institute Press, 1972).

Percy Cradock, *Know Your Enemy: How the Joint Intelligence Committee Saw the World* (London: John Murray, 2002).

Peter Cremer, *U333: The Story of a U-boat Ace*, tr. Lawrence Wilson (London: The Bodley Head, 1984).

John Creswell, *British Admirals of the Eighteenth Century* (London: Allen & Unwin, 1972).

John Creswell, *Naval Warfare: An Introductory Study* (*London*: Sampson Low, Marston & Co., 1942).

Viscount Cunningham of Hyndhope, *A Sailor's Odyssey* (London: Hutchinson & Co., 1951).

Thurston Dart, *The Interpretation of Music* (New York: Harper, 1963).

Michael Dockrill, *The Cold War, 1945-1963*, (London: Macmillan, 1988).

Karl Doenitz, *Memoirs: Ten Years and Twenty Days*, tr. R.H. Stevens, intro. Jürgen Rohwer (London: Greenhill Books, 1990).

Martin Doughty, *Merchant Shipping and War: A Study in Defence Planning in Twentieth-Century Britain* (London: Royal Historical Society, 1982).

W.A.B. Douglas, Roger Sarty, Michael Whitby, *No Higher Purpose: The Official Operational History of the Royal Canadian Navy in the Second World War, 1939-1943*, Vol. II, Part 1 (St. Catherines, Ontario: Vanwell Publishing Limited, 2002).

W.A.B. Douglas, *The Creation of a National Air Force: The Official History of the Royal Canadian Air Force*, Vol. II (Toronto: University of Toronto Press, 1986).

David Edgerton, *England and the Aeroplane: an Essay on a Militant and Technological Nation* (Basingstoke: Macmillan, 1991).

Dwight D. Eisenhower, Crusade in Europe (London: William Heineman, 1948).

Giuseppe Fioravanzo, *A History of Naval Tactical Thought*, tr. Arthur W. Holst (Annapolis: United States Naval Institute, 1979).

George Franklin, *Britain's Anti-Submarine Capability, 1919-1939* (London: Frank Cass, 2003).

Norman Friedman, *The Fifty Year War: Conflict and Strategy in the Cold War* (Annapolis: Naval Institute Press, 2000).

Norman Friedman, *U.S. Submarines Since 1945: An Illustrated Design History* (Annapolis: U.S. Naval Institute Press, 1994).

Norman Friedman, *The Postwar Naval Revolution* (London: Conway, 1986).

Norman Friedman, *Submarine Design and Development* (London: Conway, 1984).

Michael Gannon, *Black May: The Epic Story of the Allies' Defeat of the German U-Boats in May 1943* (London: Aurum Press, 1998).

W.J.R. Gardner, *Decoding History: The Battle of the Atlantic and Ultra* (London: Macmillan, 1999).

F.N. Goodwin, *Castle Class Corvettes (Frigates): An Account of the Service of the Ships and their Ships' Companies* (Castle Class Corvette (Frigate) Association (forthcoming)).

S.G. Gorshkov, *The Sea Power of the State* (Annapolis, Maryland: Naval Institute Press, 1976, translated 1979).

Christina J.M. Goulter, *A Forgotten Offensive: Royal Air Force Coastal Command's Anti-Shipping Campaign, 1940-1945* (London: Frank Cass, 1995).

William Granville, *Sea Slang of the Twentieth Century* (*London*: Winchester Publications, Ltd., 1949).

Peter Gretton, *Crisis Convoy: The Story of HX231* (London: Peter Davies, 1974).

Peter Gretton, *Convoy Escort Commander* (London: Cassell, 1964).

Eric J. Grove (ed.), *The Defeat of the Enemy Attack on Shipping, 1939-1945*, revised edn. (Aldershot: Ashgate for The Navy Records Society, 1997).

Eric J. Grove, *Vanguard to Trident: British Naval Policy since World War II* (London: The Bodley Head, 1987).

Willem Hackmann, *Seek & Strike: Sonar, Anti-submarine Warfare and the Royal Navy 1914-54* (London: HMSO, 1984).

Arnold Hague, *The Allied Convoy System, 1939-1945: Its Organisation, Defence and Operation* (Annapolis, Maryland: Naval Institute Press, 2000).

Paul G. Halpern, *A Naval History of World War I* (London: UCL Press, 1994).

Peter Hennessy, *The Secret State: Whitehall and the Cold War* (London: Allen Lane, 2002).

Günther Hessler, *The U-boat War in the Atlantic, 1939-1945*, Vol. III: *June 1943 – May 1945* (London: HMSO, 1989).

High Command of the Navy, *The U-Boat Commander's Handbook, 1942, New Edition 1943*, (Gettysburg, PA: Thomas Publications, 1989).

F.H. Hinsley, E.E. Thomas, C.F.G. Ransom & R.C. Knight, *British Intelligence in the Second World War: Its Influence on Strategy and Operations*, Vol. III, Part 1 (London: HMSO, 1984).

F.H. Hinsley, E.E. Thomas, C.A.G. Simkins and C.F.G. Ransom, *British Intelligence in the Second World War: Its Influence on Strategy and Operations*, Vol. III, Part 2 (London: HMSO, 1988).

D. Howse, *Radar at Sea. The Royal Navy in World War* 2 (London: Macmillan for The Naval Radar Trust, 1993).

Michael T. Isenberg, *Shield of the Republic: The United States Navy in an Era of Cold War and Violent Peace, 1945-1962* (New York: St. Martin's Press, 1993).

Admiral of the Fleet, Viscount Jellicoe of Scapa, *The Crisis of the Naval War* (London: Cassell, 1920).

F.A. Kingsley (ed.), *The Development of Radar Equipments for the Royal Navy, 1935-1945* (London: Macmillan Press, for the Naval Radar Trust, 1995).

M. Llewellyn-Jones (ed.), *The Royal Navy and the Mediterranean Convoys to Malta in World War Two* (London: Cass, forthcoming).

M. Llewellyn-Jones (ed.), *The Royal Navy and the Arctic Convoys to Russia in World War Two* (London: Cass, forthcoming).

Bernard Lovell, *P.M.S. Blackett: A biographical memoir* (London: The Royal Society, 1976).

Edward N. Luttwak, *Strategy: the Logic of War and Peace* (Cambridge, Mass.: Harvard University Press, 1987).

A.T. Mahan, *The Influence of Sea Power upon the French Revolution and Empire, 1793-1812*, Vol. I (Boston: Little, Brown & Co., 1895).

A.T. Mahan, *The Influence of Sea Power upon History, 1660-1783* (*London*: Sampson Low, Marston, Searle & Rivington, c.1889).

Joseph A. Maiolo, *The Royal Navy and Nazi Germany, 1933-39: A Study in Appeasement and the Origins of the Second World War* (London: Macmillan Press, 1998).

Chris Madsen, *The Royal Navy and German Naval Disarmament, 1942-1947* (London: Frank Cass, 1998).

Janet M. Manson, *Diplomatic Ramifications of Unrestricted Submarine Warfare, 1939-1941* (London: Greenwood Press, 1990).

Arthur J. Marder, *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904-1919*, Vol. IV: *1917: Year of Crisis* (London: Oxford University Press, 1969).

Leo Marriott, *Royal Navy Destroyers since 1945* (London: Ian Allan, 1989).

Leo Marriott, *Royal Navy Frigates since 1945*, 2nd edn. (London: Ian Allan, 1990).

Dwight R. Messimer, *Find and Destroy: Antisubmarine Warfare in World War I* (Annapolis, Maryland: Naval Institute Press, 2001).

Marc Milner, *The U-boat Hunters: The Royal Canadian Navy and the Offensive against Germany's Submarines* (Annapolis, Maryland: Naval Institute Press, 1994).

James L. Money (ed.), *The Dictionary of American Naval Fighting Ships*, Vol. VI, Historical Sketches – Letters R through S (Washington, DC.: United States Government Printing Office, 1976).

Richard Moore, *The Royal Navy and Nuclear Weapons* (London: Frank Cass, 2001).

Naval Staff Directorate, *British Maritime Doctrine*, 2 Edn., BR1806, (London: HMSO, 1999).

Navy List, various.

Henry Newbolt, *History of the Great War: Naval Operations*, Vol. V (London: Longmans, 1931).

Axel Niestlé, *German U-boat Losses during World War II: Details of Destruction* (London: Greenhill, 1998).

D.P. O'Connell, *The Influence of Law on Sea Power* (Manchester: Manchester University Press, 1975).

Richard Overy, *The Battle*, (London: Penguin, 2000).

Michael A. Palmer, *Origins of the Maritime Strategy: The Development of American Naval Strategy, 1945-55* (Annapolis: Naval Institute Press, 1990).

Kenneth Poolman, *Escort Carrier, 1941-1945: An Account of British Escort Carriers in Trade Protection* (London: Ian Allan, 1972).

D.A. Rayner, *Escort: the Battle of the Atlantic* (London, William Kimber, 1955).

Terrence Robertson, *Walker RN* (London: White Lion edn., 1975).

N.A.M. Rodger, *The Admiralty* (Lavenham: T. Dalton, 1979).

Jürgen Rohwer and Mikhail S. Monakov, *Stalin's Ocean-Going Fleet: Soviet Naval Strategy and Shipbuilding Programmes, 1935-1953* (London: Frank Cass, 2001).

Jürgen Rohwer, *Axis Submarine Successes of World War Two: German, Italian and Japanese Submarine Successes, 1939-1945* (London: Greenhill Books, 1999.

Jürgen Rohwer, *The Critical Convoy Battles of March 1943: The Battle for HX.229/SC.122* (London: Ian Allan, 1977).

S.W. Roskill, *Naval Policy Between the Wars*, Vol. II: *The Period of Reluctant Rearmament, 1930-1939* (London: Collins, 1977).

S.W. Roskill, *The Strategy of Sea Power: It Development and Application* (London: Collins, 1962).

Stephen Roskill, *The War at Sea 1939-1945*, Vol. I: *The Defensive* (London: HMSO, 1954).

Stephen Roskill, *The War at Sea 1939-1945*, Vol. III, Part II: *The Offensive 1 June 1944-14 August 1945* (London: HMSO, 1961).

Eberhard Rössler, *The U-boat: The Evolution and Technical History of German Submarines*, tr. Harold Erenberg (London: Arms and Armour Press, 1981).

Jon Tetsuro Sumida, *Inventing Grand Strategy and Teaching Command: The Classic Works of Alfred Thayer Mahan Reconsidered* (London: The John Hopkins University Press, 1997).

Robert C. Stern, *Type VII U-boats* (London: Arms and Armour Press, 1997).

David Syrett (ed.), *The Battle of the Atlantic and Signals Intelligence: U-Boat Situations and Trends, 1941-1945* (Aldershot: Ashgate, 1998).

David Syrett, *The Defeat of the German U-Boats: The Battle of the Atlantic* (Columbia: South Carolina University Press, 1994).

John Terraine, *Business in Great Waters: The U-Boat Wars 1916-1945* (London: Leo Cooper, 1989).

Robert J. Urick, *Principles of Underwater Sound*, 3 edn. (California: Peninsula Publishing, 1983).

Jordan Vause, *Wolf: U-boat Commanders in World War II* (Shrewsbury: Airlife, 1997).

C.H. Waddington, *OR in World War 2: Operational Research against the U-boat* (London: Elek Science, 1973).

D.W. Waters, *Convoy as a Mine Countermeasure in Two World Wars* (Admiralty: Historical Section, 1953).

Anthony J. Watts, *The U-Boat Hunters* (Abingdon, Oxon.: Purnell Book Services, 1976).

Gary E. Weir, *Forged in War: The Naval-Industrial Complex and American Submarine Construction, 1940-1961* (Washington: Naval Historical Center, Department of the Navy, 1993).

D.E.G. Wemyss, *Walker's Groups in the Western Approaches* (Liverpool: Daily Post and Echo Ltd., c. 1948).

R. Whinney, *The U-boat Peril: An Anti-Submarine Commander's War* (Poole: Blandford, 1986).

Mark Williams, *Captain Gilbert Roberts RN and the Anti-U-Boat School* (London: Cassell, 1979).

John Winton, *Convoy: The Defence of Sea Trade 1890-1990* (London: Michael Joseph, 1983).

Who's Who, various.

Kenneth Wynn, *U-Boat Operations of the Second World War*, Vol. 2: *Career Histories, U511-UIT25* (London: Chatham Publishing, 1998).

William T. Y'Blood, *Hunter-Killer: US Escort Carriers in the Battle of the Atlantic* (Annapolis, Ma.: Naval Institute Press, 1983).

Articles

P.M.S. Blackett, 'Evan James Williams. 1903-1945,' in *Obituary Notices of Fellows of The Royal Society*, 1945-1948, Vol. V (London: Morrison & Gibb for The Royal Society, 1945-1948).

R.A. Brie, 'Rotary-wings at Sea,' *The Aeroplane* (6 July 1951).

E. Maurice Chadwick, 'The Night the Gnats Bit,' in *Starshell*, Vol. VI, No. 7 (Fall 1997), pp. 11-12.

David Edgerton, 'From Innovation to Use: Ten Eclectic Theses on the Historiography of Technology,' *History of Technology*, Vol. 16, No. 2 (1999), pp. 111-136.

David Edgerton, 'The Prophet Militant and Industrial: the Peculiarities of Correlli Barnett,' *Twentieth Century British History*, Vol. 2 (1991), pp. 360-379.

Ralph Erskine, 'Kurier,' n.d., Paper kindly supplied by author, 7 December 1999.

G.D. Franklin, 'A Breakdown in Communications: Britain's Over Estimation of Asdic's Capabilities in the 1930s,' *The Mariner's Mirror*, Vol. 84, No. 2 (May 1998), pp. 204-214.

W.J.R. Gardner, 'Blackett and the Black Arts,' in, Peter Hore (ed.), *Patrick Blackett: Sailor, Scientist, Socialist* (London: Frank Cass, 2003), pp. 126-137.

Andrew Gordon, 'The Doctrine Pendulum,' in Peter Hore (ed), *Hudson Papers*, Vol. 1 (Ministry of Defence, 2001), pp. 73-102.

P. Gretton, 'Why Don't We Learn From History,' *The Naval Review* (January 1958).

Eric Grove and Geoffrey Till, 'Anglo-American Maritime Strategy in the Era of Massive Retaliation, 1945-60,' in John B. Hattendorf and Robert S. Jordan (eds.), *Maritime Strategy and the Balance of Power: Britain and America in the Twentieth Century* (Basingstoke, Hants.: Macmillan Press, 1989).

Eric J. Grove, 'The Post War "Ten Year Rule" - Myth and Reality,' *Journal of the Royal United Services Institute*, Vol. 129, No. 4 (December 1984), pp. 48-53.

John B. Hattendorf, 'Maritime conflict,' in, Michael Howard, George J. Andreopoulos and Mark R. Shulman (eds.), *The Laws of War: Constraints on Warfare in the Western World* (London: Yale University Press, 1994).

Holger H. Herwig, 'Innovation Ignored: The Submarine Problem, Germany, Britain, and the United States, 1919-1939,' in, Williamson Murray and Allan R. Millett (eds.), *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), pp 227-264.

Wayne P. Hughes, Jr., 'The Strategy-Tactics Relationship,' in Colin S. Gray and Roger W. Barnett (eds.), *Seapower and Strategy* (Maryland, Annapolis: Naval Institute Press, 1989).

G.J. Kirby, 'A History of the Torpedo: Part 3,' *Journal of the Royal Naval Scientific Service*, Vol. 27, No. 2 (1972).

Andrew Lambert, 'Seapower 1939-1940: Churchill and the Strategic Origins of the Battle of the Atlantic,' in, Geoffrey Till (ed.), *Seapower: Theory and Practice* (Essex, Ilford: Frank Cass, 1994).

'The Overall Strategic Plan, May 1947 (DO(47)44 (Also COS(47)102(0)) (Retained – Cab Off)),' Appendix 7, in, J. Lewis, *Changing Direction: British Military Planning for Post-war Strategic Defence, 1942-1947* (London: The Sherwood Press, 1988).

M. Llewellyn-Jones, 'The Pursuit of Realism: British Anti-Submarine Tactics and Training to Counter the Fast Submarine,' in, John Reeve and David Stevens (eds.), *The Face of Naval Battle: The Human Experience of Modern War at Sea* (Crows Nest, NSW, Australia: Allen & Unwin, 2003), pp. 219-239.

M. Llewellyn-Jones, 'A Clash of Cultures: The Case for Large Convoys,' in, Peter Hore (ed.), *Patrick Blackett: Sailor, Scientist, Socialist* (London: Frank Cass, 2003).

M. Llewellyn-Jones, 'A Flawed Contender: The "Fighter" Submarine, 1946-1950,' in Martin Edmonds (ed.), *100 Years of the Trade: Royal Navy Submarines Past, Present & Future* (University of Lancaster: Centre for Defence and International Security Studies, February 2001), pp. 58-67.

M. Llewellyn-Jones, 'Trials with HM Submarine *Seraph* and British Preparations to Defeat the Type XXI U-Boat, September–October, 1944,' *The Mariner's Mirror*, Vol. 86, No. 4 (November 2000), pp. 434-451.

M. Llewellyn-Jones, 'Clay Blair Jr., *Silent Victory: The US Submarine War Against Japan*. Annapolis, Maryland: Naval Institute Press, 2001 (original 1975). 1071 pp., maps, photographs, appendices, bibliography, index. US$32.50, paper; ISBN 1-55750-217-X,' Book Review in *The Northern Mariner* (forthcoming).

Joseph Maiolo, 'Deception and Intelligence Failure: Anglo-German Preparations for U-boat Warfare in the 1930s,' Paper delivered at the Military History Seminar, King's College, London, 23 February 1999.

Douglas M. McLean, 'Confronting Technological and Tactical Change: Allied Antisubmarine Warfare in the Last Year of the Battle of the Atlantic', *Naval War College Review*, Vol. 47, No. 1 (1994), pp. 87-104.

Doug McLean, 'The U.S. Navy and the U-Boat Inshore Offensive,' in William B. Cougar (ed.), *New Interpretations in Naval History: Selected Papers from the Twelfth Naval History Symposium* (Annapolis: Naval Institute Press, 1997), pp. 310-324.

Marc Milner, 'The Dawn of Modern Anti-Submarine Warfare: Allied responses to the U-boats, 1944-45,' *RUSI Journal* (Spring 1989), pp. 61-68.

W. Murray, 'Neither Navy was Ready,' *United States Naval Institute Proceedings*, No. 107 (1981).

T.H. Pratt, 'A Rose by Any Other Name: An Outline of Operational Analysis in Admiralty HQ, 1947-1970,' *Journal of Naval Science*, Vol. 7, No. 1 (January 1981), pp. 2-9.

Henry Probert, 'Allied Land-Based Anti-Submarine Warfare,' in Stephen Howarth and Derek Law (eds.), *The Battle of the Atlantic 1939-1945: The 50th Anniversary International Naval Conference* (London: Greenhill Books, 1994).

Robin Ranger, 'The Anglo-French Wars, 1689-1815,' in Colin S. Gray and Roger W. Barnett (eds.), *Seapower and Strategy* (Maryland, Annapolis: Naval Institute Press, 1989).

N.A.M. Rodger, 'Image and Reality in Eighteenth-Century Naval Tactics,' *The Mariner's Mirror*, Vol. 89, No. 3 (August 2003), pp. 280-296.

David Syrett, 'The Battle for Convoy OG69, 20-29 July 1941,' *The Mariner's Mirror*, Vol. 89, No. 1 (February 2003), pp. 71-81.

Michael Whitby, 'The Strain on the Bridge,' in, John Reeve and David Stevens (eds.), *The Face of Naval Battle: The Human Experience of Modern War at Sea* (Crows Nest, NSW, Australia: Allen & Unwin, 2003), pp. 200-218.

H.P. Willmott, 'The Organisations: The Admiralty and the Western Approaches,' in, Stephen Howarth and Derek Law (eds.), *The Battle of the Atlantic 1939-1945: The 50th Anniversary International Naval Conference* (London: Greenhill Books, 1994).

R.E. Woolven, 'Coastal Command's Early ASV Radars,' *Air Clues: The Royal Airforce Magazine*, Vol. 24, No. 5 (February 1970).

David Zimmerman, 'Tactics and Technology', in Stephen Howarth and Derek Law (eds.), *The Battle of the Atlantic 1939-1945: The 50th Anniversary International Naval Conference* (London: Greenhill Books, 1994).